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A Framework for Evaluating Technology-Mediated Collaborative Workflow

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by

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ABSTRACT

The adoption of new technology into collaborative workflows has permeated every aspect of our personal and professional lives with the promise of performing work processes more efficiently and with greater capability. The continued rise of ubiquitous computing and heightened need for collaborative features suggest that a view of enabling technologies in a workflow should include the physical computing infrastructure, the collaborative interaction between humans and computers, and the informatics (i.e., collection and representation of data within the workflow). The development and integration of technology for collaborative workflows introduces many variables that are of great concern to companies, organization, and individuals. These variables include the costs of development, the switching cost associated with migrating from the current workflow to the technology-enhanced workflow, and details of how the technology-mediated workflow functions compare to the current workflow functions. There is, however, no consistent, generalizable approach to evaluate and compare an existing workflow with the enhanced technology-mediated workflow in a manner that identifies improvements and barriers in replicable qualitative and quantitative measures.

In order to develop such a consistent, generalizable approach, this research investigates what necessary set of cross-disciplinary metrics and methodology is required to effectively evaluate technology-mediated collaborative workflow through an analysis of related works from four disciplines (Social Sciences, Organization and Behavioral Management, Industrial Engineering, and Human-Computer Interaction). The research introduces the Collaborative Space – Analysis Framework (CS-AF), a cross-disciplinary model and methodology designed to evaluate and compare collaborative workflows. The research includes testing the CS-AF model using two diverse empirical studies designed to evaluate a current-state workflow, compared to a technology-mediated workflow on five key collaborative areas (Context, Technology, Process, Attitude and Behavior, and Outcomes). The research incorporates the CS-AF model and methodology to test the effectiveness of the approach for capturing and analyzing essential quantitative and qualitative parameters of the collaborative workflows.

The second empirical study tested hypertensive patients currently involved in clinical maintenance with regular outpatient monitoring. The test included 50 hypertension patients, selected based on matched-pairs for age and gender to test the workflow model in a 3-week trial. All participants were tested on an existing workflow (current-state), then the population was randomly split within pairs. The matched-pairs were assigned to one of two alternative workflows: 25 patients were introduced to a manual hypertension self-exam workflow (control group), and their matched-pair counterparts were introduced to technology-mediated hypertension self-exam workflow. All participants were tested on the existing workflow (current-state), followed by the introduction of an alternate workflow, and then tested a second time (pre-/ post-) with the same CS-AF procedure. The study incorporated the research findings from these two tests and a comparison between the workflows introduced using the CS-AF metrics.

Findings from the two diverse empirical studies using the CS-AF (Graphic Communications sales order process, and Health Information Technology hypertension exam workflow) indicate that technology-mediated workflows do improve collaborative performance; however, adoption is not as pronounced as hypothesized. The research findings indicate that the lack of acceptance is due to non-technology factors, such as attitude and behavior, which play a significant role in adoption and need similar attention as technology innovation to drive true adoption and ultimately better collaborative performance. The research findings also indicate that the effectiveness of the CS-AF may have potential as a generalizable approach for evaluating technology-mediated collaborative workflow in a variety of unique domains.

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Chapter 1

Introduction

1.1. Overview

The adoption of new technology has permeated every aspect of our personal and professional lives with the promise of performing work processes more efficiently and with greater capability. In 1984, the term, “computer-supported cooperative work,” (CSCW) was coined by Grudin [1:19] in order to focus on the “understanding of the way people work in groups with enabling technologies,” i.e., technology-mediated workflows. This research builds on the core CSCW mission with an updated context for CSCW to include the seamless integration of the three key elements of infrastructure, interaction (i.e., collaboration), and informatics into a platform or system aimed at improved efficiency and expanded capability.

The continued rise of ubiquitous collaborative computing and wide-scale use of data suggests that a view of enabling technologies in a workflow should include the physical computing infrastructure, the collaborative interaction between humans and computers (HCI), and informatics (i.e., the collection and representation of data within the workflow). Infrastructure includes the hardware, software, and communications technology that are developed and integrated into a workflow to enhance or enable an activity, task, or work practice [2]. Interaction involves the user interface and collaborative experience established between two or more entities that are intended to work cooperatively to accomplish a specific activity, task, or work practice [3]. Informatics incorporates the collection, classification, storage, processing, analysis, and interpretation of data encountered within the workflow [4].

New technologies impact the way we function in our daily lives – both from a personal perspective as consumers and in our professional lives as knowledge workers. The integration of new technology into collaborative workflows introduces many variables that are of great concern to companies, organization, and individuals. These variables include the costs of development, the switching cost associated with migrating from the current workflow to the future workflow, and details of how the future workflow functions, compared to the current workflow. What processes should be avoided? What should be retained? What should be revised? How is user behavior associated with adoption of the new technology? Organizations have a difficult time determining the scope of a new technology initiatives, including how the capability and complexity of new technology will provide measurable benefit in some quantified or qualified way, compared to the current workflow. This research includes a review and analysis of related works from several unique disciplines, the creation of a collaborative evaluation model and methodology (the Collaborative Space – Analytical Framework, or CS-AF), two comprehensive field tests and associated analysis using this new approach (model and methodology), and a case for generalizability of the model and methodology for use in other domains.

1.2. Problem Statement

The development and integration of technology for collaborative workflows introduces many variables that are of great concern to companies, organization, and individuals. These variables include the costs of development, the switching cost associated with migrating from the current workflow to the technology-enhanced workflow, and details of how the technology-mediated workflow functions, compared to the current workflow. There is however, no consistent approach to evaluate and compare an existing workflow with the enhanced technology-mediated workflow in a manner that identifies the improvements and barriers in replicable qualitative and quantitative measures.

In most instances, major enhancements to a targeted workflow deliver operational efficiency and increased capability, resulting in increased productivity and innovative ways to perform work processes; yet seldom is the gain associated with the technology-mediated workflow quantified in a measurable or meaningful manner. Companies and users are quick to scoop up the gains in productivity and capability, leaving developers to rationalize their value-add and to identify the next wave of features and functionality required to support continuous improvement. The graphic communications industry and other workflow-intense industries, such as health-information technology, have had difficulty characterizing the relationship between the current-state collaborative workflows and progress made through technology-mediated workflow enhancements. This research delivers a generalizable and multi-disciplinary approach to evaluate the association between an existing workflow and the possible gains and gaps delivered by technology-mediated enhancements to the workflow. This research introduces and validates a consistent multi-faceted approach to evaluating a collaborative workflow in its current state, compared to an enhanced technology-mediated workflow, quantifying and comparing the improvements and gaps associated with the enhancements. The objective for this research is to deliver a comprehensive and generalizable model and methodology that can be used to evaluate collaborative-intense workflows in a variety of domains.

1.3. Motivation

Motivation for this research comes from observations made over three decades of implementing technology-mediated workflows in the graphic communications industry, both as a practitioner and as a researcher/developer. The work of evaluating collaborative workflows (specifically by investigating gaps and barriers) began with first-hand empirical investigations using a somewhat naturalistic approach, and over time, has expanded to include positivism techniques that complement a balanced approach to study workflow in the natural setting, while extracting valuable data in a structured enough method to drive both business and technology decisions.

A consultative workflow discovery methodology originating from the Solutions Engineering team at Xerox (designed to engage customers in the document assessment process) was the foundational building block for what would become the Xerox Lead Document Production (LDP) process and methodology spearheaded by Rui et al. [5]. This program evolved to become an GC industry best-practice approach to uncovering collaborative workflow gaps that might be addressed by technology improvement.

A worldwide Solutions and Engineering Services group at Eastman Kodak was similarly tasked. The group was involved in workflow assessments and live workflow integrations that incorporated Kodak technologies and often custom software development; it engaged with many Kodak customers conducting the patented Business Opportunity Assessment (BOA) to transform workflows incorporating new technology with better efficiency and expanded features [6].

Both the Xerox LDP and the Kodak BOA methodology incorporated Lean principles and Value Stream Mapping (VSM) in order to evaluate and collect data regarding a target workflow. However, the methods did not incorporate other important aspects of the collaborative workflow experience, such as context, behavior, attitude, goals, and information quality. The expanded use of computers in every discipline has put an enormous stress on the development process – to get the development right means better anticipation of collaborative user needs for all aspects of the workflow. This research is an opportunity to expand on that prior commercial work to include other critical disciplines that are essential to collect and evaluate a more comprehensive view of collaborative workflows.

The essence of my Masters thesis research, *Immersion & Iteration: Leading Edge Approaches for Early Stage Product Planning* [7], is a proposed new method to expand the traditional product development lifecycle, with more in-depth ethnographic research regarding the target design space and associated workflow where the opportunity for new product development resides. That research pointed to case studies of major product innovations that were achieved by companies that invested the extra time and money on the front end of the product development process in order to capture real user activities in their environment.

This current research is directed towards a novel and functional interdisciplinary approach (i.e., model and methodology) to target a specific workflow, evaluate that workflow as it exists, transform the workflow with new technology-mediated innovation, and re-check the new workflow to evaluate whether gains and/or gaps exist in comparison to the initial workflow. A comprehensive empirical study was conducted in the graphic communications space, and a second empirical study was conducted for the health information technology space. In light of the 2020 COVID-19 pandemic, new paradigms for successful delivery of remote healthcare services have been explored and implemented out of necessity. Demand for telehealth solutions that facilitate collaborative and remote workflows between doctors and patients has increased, creating a forcing-function for all to adopt new approaches of medical practice engagement. Due to the pandemic and the need to engage remotely (both synchronously and asynchronously), technology adoption trends towards telehealth have greatly accelerated. The surge of pandemic-driven demand and reactive technology innovation further underscores the motivation of this research to establish a replicable framework to evaluate cross-disciplinary attributes of technology-mediated collaborative workflow enhancements.

1.4. Research Questions

This research includes the analysis of related works and collaborative workflow measures from four disciplines (Behavioral Science, Organization Management, Industrial Engineering, and HCI/CSCW) in efforts to address three key research questions.

RQ1: *What set of cross-disciplinary metrics and consistent methodology are necessary to effectively evaluate a technology-mediated collaborative workflow?*

RQ2: *Do the metrics and methodology introduced in the CS-AF produce an effective evaluation of the technology-mediated collaborative workflow for the graphic arts and hypertension workflows evaluated?*

Based on related works that evaluate and compare collaborative context, technology adoption, workflow optimization, collaborative awareness, and goal alignment, the CS-AF was formed. (See the detailed description in Chapter 3.) The CS-AF model and methodology developed for this research include the collection and analysis of quantitative and qualitative data (measures, suggestions, observations, and insights), based on related work from a variety of disciplines, including HCI/CSCW, social sciences, organizational management, and industrial engineering (RQ1). By combining an intradisciplinary view of collaborative workflow, and quantitative and qualitative data from both the current-state and technology-mediated workflow, the CS-AF (model and methodology) enables the analysis between a current-state and a technology-mediated collaborative workflow (RQ2).

RQ3: *Does the CS-AF and methodology deliver an effective generalizable approach to evaluate technology-mediated collaborative workflows across different domains?*

The generalizability of the CS-AF model and methodology (RQ3) developed for this research was validated through two comprehensive and diverse empirical studies that include the following research components using the CS-AF: current-state workflow evaluation, technology-mediated workflow development, implementation, and workflow analysis, and comparison analysis between the current-state and technology-mediated collaborative workflows.

- Graphic Communications (GC) domain: Sales Quotation Workflow, Business-to-Business (B2B) collaborative workflow example (Chapter 4).
- Health Information Technology (HIT) domain: Hypertension Exam Workflow, Business-to-Consumer (B2C) collaborative workflow example (Chapter 5).

From related works, the initial CS-AF developed for this research was used in an empirical study for a Graphic Communications example. This field engagement effort provided an opportunity to test the CS-AF approach, evaluate the effectiveness of the methodology, refine the CS-AF as needed, and positioned the research for a second empirical study targeted at hypertension collaborative workflow, for which the following hypotheses had been formed:

1.6.1 Research Hypotheses

Primary Hypothesis H1: *Consistent and Diverse Data Hypothesis: It is hypothesized that the CS-AF will produce* ***consistent data from a diverse set of parameters that will deliver a meaningful comparison*** *between the current-state and technology-mediated workflows evaluated.*

The workflow specific hypothesis for each of the CS-AF determinants are covered with H1 secondary hypothesis H1.1 to H1.12. Each of the secondary hypothesis are evaluated through results of the CS-AF survey instrument that is administered at the start of the study for the existing or current-state workflow and then repeated (same survey questions) following the habituated use of the technology-mediated workflow. The comparison between the two pre-post CS-AF surveys are used to determine the hypothesis results.

CS-AF Attribute	Secondary Workflow Specific Hypothesis H1.1 - H1.12
H1.1: **Context** Hypothesis:	*It is hypothesized that technology-mediated workflows are more asynchronous and remote, when compared with current-state workflows.*
H1.2: Process **Time** Hypothesis:	*It is hypothesized that technology-mediated workflows are more streamlined (i.e., require less time), when compared with current-state workflows.*
H1.3: Information **Quality** Hypothesis:	*It is hypothesized that technology-mediated workflows deliver better information quality, when compared with current-state workflows.*
H1.4: Perceived **Usefulness** Hypothesis:	*It is hypothesized that technology-mediated workflows are perceived to be more useful, when compared with current-state workflows.*
H1.5: Perceived **Ease-of-Use** Hypothesis:	*It is hypothesized that technology-mediated workflows are perceived to be easier to use, when compared with current-state workflows.*
H1.6: **Satisfaction** Hypothesis:*	*It is hypothesized that technology-mediated workflows are perceived to be more satisfying, when compared with current-state workflows.*
H1.7: **Ease-of-Learning**	*It is hypothesized that technology-mediated workflows are*

CS-AF Attribute	Secondary Workflow Specific Hypothesis H1.1 - H1.12
Hypothesis:*	*easier to learn, when compared with current-state workflows.*
H1.8: **Promotability** Hypothesis:*	*It is hypothesized that technology-mediated workflows are more highly promoted, when compared with current-state workflows.*
H1.9: **Attitude-Toward-Use** Hypothesis:	*It is hypothesized that the attitude to use technology-mediated workflows is more positive, when compared with current-state workflows.*
H1.10: **Behavioral Intention** Hypothesis:	*It is hypothesized that the behavioral intention to use technology-mediated workflows is more positive, when compared with current-state workflows.*
H1.11: **Awareness** Hypothesis:	*It is hypothesized that technology-mediated workflows increase the awareness of information sharing needs, when compared with current-state workflows.*
H1.12: **Goal Alignment** Hypothesis:	*It is hypothesized that technology-mediated workflows increase goal alignment, when compared with current-state workflows.*

Table 1: Secondary CS-AF Workflow Specific Research Hypotheses H1.1-H1.12
* Note: H1.6, H1.7, and H1.8 were added to the CS-AF following the GC Workflow study, prior to the HIT Workflow study.

Primary Hypothesis H2: *Effective Approach Hypothesis: It is hypothesized that the CS-AF will produce an* ***effective approach*** *(model and methodology) that can be used to evaluate current-state workflow and a technology-mediated collaborative workflow for the Graphic Communications and Health Information Technology domains.*

Primary Hypothesis H3: *Generalizable Hypothesis: It is hypothesized that versatility of the CS-AF will be viable as* ***a generalizable analysis approach*** *for both the GC workflow and the HIT workflow. It is further hypothesized that the CS-AF can be adapted to other domains where technology-mediated collaborative workflow is required.*

1.5. Need for a Generalizable Approach for Evaluating Technology-Mediated Collaborative Workflow

Evaluating technology's impact on our lives and the research of human interactions with technology has been the historic aim of computer science (CSCW, HCI, etc.); this impact has also presented an important research focus for the social sciences, organizational and behavioral science, and industrial engineering, as explained in the Related Works section [8]. To this day, CSCW and HCI continue with heightened interest to understand the obstacles and opportunities associated with integrating technology-mediated enhancements into existing workflows in order to promote better collaborative experience [1].

Two important perspectives emerge from the research of related works that are central to this research focus regarding the evaluation of collaborative technology-mediated workflow. They are the evaluation and measurement of the impact that technology-mediated enhancements have on humans, both individually and collaboratively, and the impact that new technology has on the organization, which ultimately equates to a financial impact. Researchers are consistently seeking to understand, quantify, and qualify the possible gains and gaps that new technology innovation brings to individuals and their ability to collaborate more effectively with others in a particular workflow.

The primary contributions of Weiser, one of the original authors of "ubiquitous computing," is the promotion for ethnomethodologically-oriented ethnography, which " … reveal[s] that it is not the setting of action that is the important element in design, but uncovering what people do in the setting and how they organize what they do" [9:399]. Expanded research methodologies are needed to facilitate immersive discovery in the work setting to effectively evaluate and direct the impact of technology-mediated enhancements on the collaborative workflow experience.

CSCW and HCI interest in collaborative groupware spans from individual and small-group users to larger organizational groups. From its inception, there was and continues to be contrasting views from individual/small groups to large groups, and from human-computer interaction and functionality [1]. The diverse contrast and opposing forces of these two major thrusts continues to fuel discussion and research through a natural vetting process. When CSCW was founded, there were opposing technology vantage points from the emerging use of PCs and those of large mainframe computers. The same opposing forces exists today with new emerging technologies, such as those between smartphones and cloud-based servers.

Both these perspectives are equally as important; computing systems from their inception purport a value proposition of efficiency, expanded capability, and collaborative integration for the benefit of both humans and the organization. Researcher John Carroll defines the mission of HCI as "… understanding and creating software and other technology that people will want to use, will be able to use, and will find effective when used…We (CSCW) will most likely need to develop new concepts to help us understand collaboration in complex organizations" [10:514].

With respect to the interdisciplinary view, the social, behavioral, and organizational sciences continue to have high interest and valuable research contributions into the requirements of technology-mediated enhancements, as reviewed in the Related Works section. The computer science field has expanded to incorporate human-computer interaction (HCI) as one of three main pillars (including infrastructure and informatics), knowing that it is the integrated computing system that often delivers the very means for collaborative workflows between humans to occur, workflows that otherwise may never have been possible. Further research into novel methods to evaluate the collaborative workflows and determine the impact of technology-mediate enhancements is crucial to advancing productivity and innovation [10], [11].

Weiseth et al. posit that organizations must "take action and make it possible for people to collaborate in effective ways" [12:242]. The researchers suggest that organizations must provide collaborative support in the form of organizational measures (collaborative best practices), services (collaborative process), and tools (collaborative methods) to enable technology-mediated workflow enhancements. Weiseth et al. introduced the Wheel of Collaboration Tools as a topology of collaborative functions in efforts to illuminate the important connection between the subtle day-to-day collaborative activities of workers and the integration of the "system" (infrastructure, content [information/informatics], and human-interface) for collaborative gain [12]. Fig.13 shows the Wheel of Collaboration Tools.

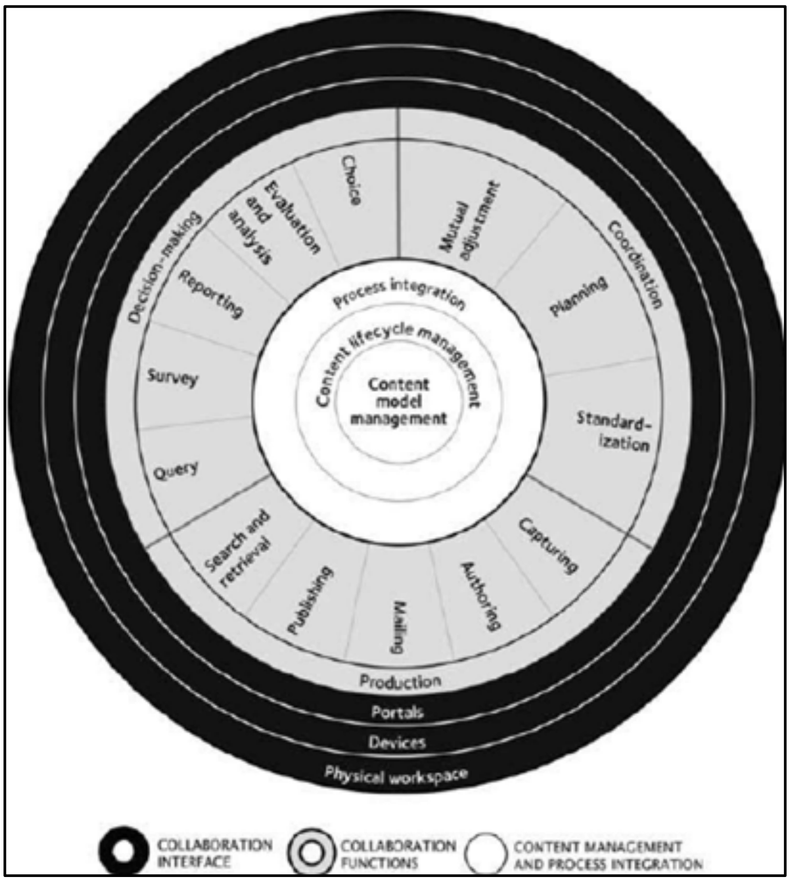


Figure 1: Weiseth et al.'s Wheel of Collaboration Tools

Weiseth et al. conducted field-analysis with the Statoil Corporation using the WCT to evaluate e-collaboration solutions. Through field experience, the researchers suggest that further work is needed to decompose this model for effective implementation, including explicit representation of process steps and a functionally integrated system (enhanced technology-mediated collaborative workflow) [12].

In their research of CSCW Models and Frameworks, researchers Neale, Carroll, and Rosson introduce the "Activity Awareness Model" (referenced in the Related Works section) and identified three historic issues associated with evaluating collaborative workflows: logistics of remote locations, complex number of variables, and the need to validate the re-engineered of future-state workflow [13]. The researchers conclude by stating, "Few methods have been developed with creating engineering solutions in mind. It is possible, but researchers must be continually cognizant about how data collection and analysis methods will translate into design solutions" [13:114]. At the core of the research findings by Neal et al. is the notion that the re-engineered workflow needs to be examined in its natural setting in order to understand the collaborative impact of the technology-mediated enhancements and that this is the "central priority in CSCW evaluation." The researchers summarize that "better evaluation approaches are critical to the successful development of CSCW applications" [13:120].

In order to accomplish the goals of ubiquitous computing and deliver collaborative human-computer interactive systems, a comparative evaluation of incremental improvements made through each technology-mediated transformation is important [14]. Kellogg et al. posit that success in HCI comes from "immersive understanding of the ever-evolving tasks and artifacts" [15:84]. Millen et al. state that understanding the context of the user environment and interaction is increasingly recognized as a key to new product innovation and good product design [16]. However, there is currently no widely-adopted generalizable model and methodology for conducting collaborative workflow analysis in a manner that addresses both the broad interdisciplinary view to provide a comparative analysis, and that includes critical qualitative and quantitative metrics. Lee and Payne suggest that "a new model is needed beyond the focus on ‘work’ or ‘technology’ to include rapidly increasing diversity of sociotechnical configurations” [17:179].

A need is apparent for a generalizable approach to evaluate a collaborative technology-mediated workflow that focuses on a specific task to be done in a specific workflow – a model that incorporates a view at the current approach, compared to the enhanced approach as a result of the new technology. Arias et al. suggest that a shift to intended use or intended work vs. the computing system is necessary [18]. Baeza-Yates posits that future work should focus on the research method, the data collection, the data analysis, and the domain of study [19]. Plowman, Rogers, and Ramage add that designers might attend to the “work” of the setting, as well as the interactional methods or practices of the members as the work is being performed. The “job of work” in the “work of a setting” are the actions and interactions that inhabit and animate the work setting [20], [21].

The aim of this research is to introduce and exercise a consistent and structural methodology to capture and evaluate the individual human collaborative experience and collective experiences of collaborative individuals in a specific and targeted workflow. The technology-mediated impact on the individual is equally as important as is the overall technology-mediated impact on groups in the organization; the re-engineered workflow needs to be recorded, evaluated, and analyzed (in comparison to the existing workflow) in order to portray an accurate view of potential gains and gaps associated with the transformation.

The primary focus of Davis’s TAM (Technology Assessment Model) and its wide-scale use (discussed in the Related Works section) is the parsimonious focus on two primary vectors used to evaluate adoption: Ease-of-Use (EU) and Perceived Usefulness (PU) [22]. At the most basic level, humans look for two resonating value propositions from new technology: an easy and more efficient way to perform an existing task, and/or opportunities for new features previously unavailable to them [22]. Davis et al. state that the “goal of the TAM is to be capable of explaining user behavior across a broad range of end-user computing technologies and user populations, while at the same time being both parsimonious and theoretically justified” [22:985].

The TAM is easy to understand and deploy, and it has been adapted by other researchers to include additional attributes that deliver complementary determinants [22]. The first modified version of the TAM was proposed in 2000, also by Davis and Venkatesh, to address two primary areas: (1) to introduce new determinants; to uncover social influences and “cognitive instrumental processes” and (2) to provide a view at specific time intervals that were meaningful to users associated with determining technology acceptance [23:187]. The notion of conducting a time view at key intervals of adoption is a particular interest of mine. In TAM 2, Davis and Venkatesh evaluate three time-intervals (pre-implementation, one-month post-implementations, and three- month post-implementations); this approach provides a valid snapshot, yet it does not go far enough to establish a detailed quantitative baseline measure that can be easily compared in a complementary sense with the qualitative survey questions. It is my belief that there is an opportunity for improvement to the TAM with more a rigorous time-interval evaluation using the Industrial Engineering (IE) technique of Value Stream Mapping (VSM) (discussed in the Related Works section.) VSM, combined with TAM and other components, will address limitations expressed with the TAM approach and introduce a much-needed task orientation to the evaluation.

In a comprehensive meta-analysis of TAM research, Yousafzai et al. posit that “usage” poses a potential issue for TAM, with many examples of TAM using self-reporting data; “… 47 per cent of the studies measured self-reported usage, less than 9 percent measured the actual usage” [24:253]. The authors believe that the “lack of task-focus in evaluating technology” has led to some mixed results. They further suggest that an opportunity to incorporate “usage models” for the TAM may strengthen predictability, yet caution is needed to manage model complexity [25:300]. The question of "usage" as a weakness of the TAM suggests that improvements with more comprehensive "use models" can be incorporated with the TAM to deliver a more robust evaluation. Specifically, this research incorporates the integration of the VSM approach used in IE (discussed in the Related Works section) to complement the evaluation breadth of the TAM.

The TAM can also be extended to include the USE questionnaire developed by Lund 2001 [26] to uncover the relationship among Ease-of-Use, Perceived Usefulness, Satisfaction, and Ease of Learning. The USE questionnaire is used to gauge the user's confidence in the system. The results of the USE analysis are represented in a four-quadrant radar chart. The percentage of positive reactions is based on the maximum percentage of positive feedback from the user experience. When the USE questionnaire is combined with traditional TAM questions and other evaluation metrics, such as Net Promoter™ [27], a more comprehensive view of each user's perspective toward the new technology can be identified and analyzed.

This research introduces a novel evaluation model and methodology incorporating approaches from multiple disciplines aimed at a generalizable approach to observe and analyze collaborative workflows. The need for a more capable approach to evaluate collaborative workflow is evidenced not only in the multidisciplinary research identified herein, but also in specific industry segments where collaborative efforts are essential. This research identifies two industry segments where collaborative workflow is mission critical: the Graphic Communications (GC) domain and the Health Information Technology (HIT) domain. The need within both the Graphic Communications and Health Information Technology domains is discussed next.

1.5.1. Graphic Communications (GC) Domain

The graphic communications industry (GC) is rooted in print manufacturing processes that have historically battled to balance the cost-tradeoffs between time and quality in efforts to disseminate all types of information via a variety of media channels. A natural friction exists in this industry between the somewhat opposing goals of the timely production of graphical content and the simultaneous pursuit of quality. Almost all GC production workflows are driven by the fundamental dynamics of time and quality, while also exhibiting a tremendous demand for real-time collaboration at each step in the workflow – from design and editorial composition through production. Researchers and practitioners are in constant search for new technologies that enhance both cycle time and capability. Most GC production firms have established a Lean approach to their operation with continuous improvement processes aimed at three key areas: operational efficiency, quality control, and expanded capability. For standardized and re-occurring production (such as that of newspapers, magazines, books, bills, statements, and some direct mail production,) great attention is focused on streamlining the manufacturing workflow to promote ease of operation, zero defects, and overall productivity. Eliminating a single operation step in a GC production workflow can not only decrease production lead-time, but also reduce cost and positively affect the bottom line. Further, increasing the collaborative abilities of the diverse participants in the GC production workflow can directly contribute to reducing production cycle-time, while increasing quality.

GC firms have traditionally employed Lean industrial engineering principles and expertise to target workflow bottlenecks. Elimination of waste and reduction of cycle-time in a large GC production workflows can equate to millions of dollars over a short period of time, making the return-on-investment (ROI) extremely attractive, therefore, making workflow re-engineering a common practice of most GC production organizations. Researchers Roth and Franchetti deployed the principles of Lean Six Sigma in their field research involving a printing company in Toledo, Ohio. The researchers worked with the firm's operational team to investigate and re-engineer their GC workflow with the goal of expanding production throughput by finding the most cost-efficient ways to utilize resources. The research team conducted an extensive ethnographic evaluation of the current-state workflow using VSM. The research team uncovered several workflow inefficiencies, and developed and implemented a refined workflow process that allowed the organization to meet expanded production goals in a more efficient manner [28].

Lean Six Sigma process improvement initiatives (as discussed above) are common in the GC industry, and they typically yield positive results when the refined workflow processes are followed. Using Lean Six Sigma and VSM techniques to investigate workflows can identify significant issues and opportunities with a rigor that can complement any ethnographic research where work processes are involved. Along with the virtues of the Lean Six Sigma process, there are some gaps that present opportunities for future research. Since Lean Six Sigma is aimed at production goals, efforts often overlook the reconciliation between the time effort and dollars spent to re-engineer the workflow, but instead focus more on the future production goals and capability. Comparing the existing workflow to the enhanced workflow can illuminate the overall gain for a more comprehensive view, not solely on the capacity that the new workflow will yield. Also, Lean Six Sigma principles are focused on waste and process inefficiencies, and do not typically address the collaborative needs of the participants in the workflow. Expanded insight into the attitude and behavior of participant in the workflow, including each participant's information needs and goals, can further illuminate subtle barriers to adoption that may impact the overall success of the future state workflow. The behavior and attitudes of the workflow participants is even more important when the workflow enhancements include technology-mediated enhancements, along with process improvements.

Acharyulu researched supply chain best practices across a sample of 70 GC printing companies in India with an aim to better understand how these companies adopt new technologies into their workflow. The research revealed that integration of digital technologies into the workflow expands the need for better communication and collaboration with customers, since the new workflows integrate the customer into the process in real time. Acharyulu states that "…there is a need to integrate internal and external operations with the usage of information technology for a seamless information flow across entire value chain, so as to operate efficiently by reducing cost" [29:44]. Establishing generalizable methods for evaluating the supply chain is a critical need for GC production organizations.

Dramatic technological advancements over the past two decades have impacted the GC industry, driving most traditional GC production organizations to completely transform their workflows with new technologies in order to maintain viability. The Digital Revolution mandates a comprehensive change to the entire supply chain, including the interface with the customer, design and composition workflows, and deployment workflows that support simultaneous and personalized delivery of print, Web, mobile, and social media content [30]. Companies that offer digital printing systems and workflows solutions (such as Xerox, Kodak, HP, and KonicaMinolta) seek to engage traditional GC firms to sell their solutions and offer consultative support to assist in the transformation effort. Xerox Corporation, for example, formed a consulting operation to investigate workflow inconsistencies and deliver formal transformation plans. The research team led by Rai et al. expanded on Lean Six Sigma principals to create a Lean Document Production (LDP) process to engage customers in a formal transformation process [5]. The research team incorporated Lean Six Sigma and VSM techniques into their methodology to identify current-state workflow issues and direct future-state technology mediated enhancements. Although the LDP methodology was successful for Xerox, the research team identified that, even with a solid technology implementation plan, understanding the culture, behavior and attitudes of users, and investing in collaborative initiatives and tools to help establish common-ground for all participants in the workflow was key. Success of the LDP program for Xerox came from establishing current-state baseline reference data that could be used for progress comparisons as new technologies are introduced. Incorporating Lean Six Sigma and VSM methods with new technology enhancements can ensure definitive improvements in workflow efficiency. LDP was deployed in over 100 GC printing companies between 1999 and 2007, with an "average cycle-time improvement of 50%, … [The] Xerox finance organization recorded a total increase in profit of $175 million dollars across the Xerox customer value chain from the LDP applications" [5:82].

Over time, the GC industry has implemented a variety of new emerging technologies and countless process improvement techniques, all in efforts to increase collaboration amongst workers, while expanding capability and increasing quality and cycle time. This led me to embark on an empirical study of collaborative workflow transformation in the GC industry at Cohber Press in response to the needs described herein, using a novel evaluation model and methodology developed during this research. This GC empirical study is discussed in detail in Chapter 5.

1.5.2. Health Information Technology (HIT) Domain

The Health Information Technology (HIT) domain is under constant change as new technologies that promise advanced capabilities, better precision, and more streamlined workflows for practitioners vie for mainstream adoption. The impact of new technologies on the HIT space is evidenced from both patient-consumer and doctor-practitioner perspectives. As new technologies infiltrate the market, practitioners advance to deliver seamless patient-centered care, yet new evaluation methods are necessary to address changing dynamics that technology enhancement introduces. A comprehensive and interdisciplinary view across all participants in the workflow is needed to support the information and collaboration demands of doctors and patients alike.

The patient-centered healthcare approach assumes expanded participation and collaboration by doctors and patients, yet it is riddled with gaps in the processes, technology, and human computer interaction (HCI) necessary for optimum workflow. Understanding the collaborative barriers for both doctors and patients can pave the way for system designers and developers to address the gaps necessary to deliver an effective HIT workflow. Goals for patient-centered healthcare include a reduction in hospital visits and re-admissions through proactive participation from patients, largely through software solutions. Winbladh et al. state that “patient-centered healthcare puts responsibility for important aspects of self-care and monitoring in patients’ hands, along with the tools and support they need to carry out that responsibility…Software is becoming increasingly important in patient-centered healthcare, and software intense systems are likely to become integral in prescribed treatment plans” [31]. Critical to the success of patient-centered healthcare software and tools is an understanding of the collaboration preferences between patients and doctors in a variety of contexts.

The HIT domain, like many other collaborative workflow domains, is charged with the complex task of vetting the emerging needs of users (i.e., patients and practitioners) and of assessing opportunities for new technologies that might be integrated to deliver better efficiency, new capability, or both. Technology adoption opportunities in this space are complicated by the collision of consumer electronics technology with health information technology. Wide-scale adoption of micro-health devices and Web surfing for health and wellness information have become mainstream consumer-patient activities. Simultaneously, hospitals and practitioners strive for improved connectivity through patient-portals enabled through Electronic Health Records (EHR), integration of high-tech equipment, and mining of big data as means to advance services, while making them more patient-centered. The HIT domain is a complex domain with tremendous needs for constant evaluation and advancement with new technology.

Patients are actively seeking more information regarding medical conditions, lifestyle information, treatment protocols, natural versus prescription options, etc. Surfing for medical-related content is one of the top five internet search activities [32]. Websites such as WebMD provide rich content that patients actively seek in an effort to reconcile various healthcare information options. Pew Research found that “53% of internet users 18-29 years old, and 71% of users 50-64 years old have gone online for health information” [32]. Patients armed with rich content pose a unique collaborative problem for practitioner, who must now deal with the reconciliation of non-doctor vetted content with patients. Doctors are often spending increasingly large amounts of time helping patients understand their attempts at self-diagnosis. As doctors and patients attempt to reach common ground, there is an added burden on doctors to reconcile information with patients during routine visits. Research conducted by Dr. Helft, University of Indiana, found that “when a patient brings online health information to an appointment, the doctor spends about 10 extra minutes discussing it with them” [33].

As Electronic Health Record and Personal Health Record (EHR/PHR) technology becomes more accessible, doctors and patients both look to leveraging EHRs and PHRs in order to support common goals. The International Alliance of Patients' Organizations (IAPO) states that “patient-centered healthcare is designed and delivered to address the healthcare needs and preferences of patients so that healthcare is appropriate and cost-effective.” The IAPO outlines five principles of patient-centered healthcare: “respect; choice and empowerment; patient involvement in health policy; access and support; information” [34:523]. Although many clinicians have adopted EHRs into their practice, the implementation is primarily at a clerical recording of EHR data and not at a two-way integration with the patient.

Jaspers et al.'s pre-/ post-physicians' satisfaction research using EHRs found that HIT systems should "correspond one-to-one with the goals a user set" [35] The paper also reveals that understanding the context of clinicians' activities and information needs in the context of the duties they perform is crucial to designing an effective user experience. The pervasive use of EHR data will increase opportunities for information exchange and collaboration between doctors and patients. However, advancement in EHR technology will not on its own drive wide-scale adoption. Providing the technology mechanism for patients to access electronic records does not ensure that the records will be accessed; nor does it address the subtle user experience requirements necessary to facilitate meaningful collaboration. Continuous evaluation and improvement of the system-wide integration between the clinical community and the patient community will be essential, and the appropriate evaluation methods will need to be designed to address the dynamics of a more electronic and real-time workflow.

Patients can use their PHR tethered to their EHR to view and manage private medical information, including family medical history, immunizations, medications, diagnoses, and healthcare provider information (such as clinicians), home monitoring devices, wearables, etc. [36]. However, the complexity of navigating through various disparate systems and software in order to gain an integrated understanding or vantage point can often become a significant gap for patients who desire to be more connected with their health information.

Further integration complexity is introduced for patients with the growing number of personalized microsensor devices available. Wearables provide microdata on patient activities, yet often do not provide an easy way to integrate microdata with other data for better insights. The research of Fritz et al. extends the use of sensing devices for personal activity; it found a true affinity for microdata with participants. "Most participants reported that the use of the device had motivated or helped them make durable changes" [37:149]. Mankoff et al. researched the use of sensors for a health-aware grocery shopping experience and found that there is important value “integrating ambiguous data into a capture and access system” [38:137]. Future HIT systems will need to incorporate a variety of unique data types from several vantage points, microdevices, the internet, CDSSs, EHRs/PHRs, etc.

Real-time patient data from non-clinical sources, such as microdevices, has valuable potential to enhance patient-centered care, yet clinicians are not inclined to reference that data, since there is no standardization of the data nor of the interface. Estrin states that we need to capture and record our small data. “Systems capture data reported by clinicians and about clinical treatment (EHR), not patients’ day-to-day activities” [39:33]. The microdata from daily activities can be leveraged with other data to provide a 360-degree patient view. Estrin is also the co-founder of Open mHealth, a nonprofit organization whose charter is to “break down the barriers to integration, bringing clinical meaning to digital health data” [39:34]. This organization is working to provide an open-source platform for those interested in the integration and harmonization of all health data (including microdata and EHR/PHR data) for a more effective experience. Even though the potential exists for better integration with patients and doctors, the collaborative benefits will never be realized to its full extent without rigorous evaluation and iteration of new technologies aimed at a streamlined workflow between doctors and patients. Consumer products and big or small data initiatives that do not involve the clinician community from the onset are destined for failure.

Collaboration is the fulcrum point for enabling optimized workflow in HIT systems. A complete understanding of collaboration is essential in order to refine certain aspects of the workflow that affect a streamlined process. Weir et al. provide a functional definition of collaboration as “the planned or spontaneous engagements that takes place between individuals or among teams of individuals, whether in-person or mediated by technology, where information is exchanged in some way (explicitly, i.e., verbally/written; or implicitly, i.e., through shared understanding of gestures, emotions, etc.), and often occur across different roles (i.e., physician and nurse) to deliver patient care" [40:64].

Successful HCI comes from an immersive understanding of the ever-evolving "tasks and artifacts" required by a specific user population [15] The careful interpretation of human activities that get translated to unmet needs and wants is at the core of the HCI mission for user-centered design [14]. Immersive discovery is essential to designing HCI systems that address the collaborative needs of users. Millen states that "understanding the context of the user environment and interaction is increasingly recognized as a key to new product/service innovation and good product design" [16]. The research of Arias et al. shifts system design to the intended use or "intended work," versus the computing system. The research found that collaborative design facilitates a shared understanding through a more engaged interaction [18].

Research findings by Skeels and Tan on HIT inpatient settings indicate that more collaborative communications across the "care setting" can provide a large impact on the quality of services for patients [41]. Successful integration of personalized health data with other meaningful data sources is an important HCI requirement for end-to-end HIT solutions. Patients can benefit from the integrations of (1) big data (relevant segmentation data aggregated from EHR or other lifestyle sources) and (2) personalized microdata (real-time data captured from patient's devices) that is referenced to PHR data. Doctors can also benefit from a real-time view into the patients' various data sources, while continuing to reference other clinical systems (e.g., CDSSs). Convertino et al. found that collaborative performance improved through an increase in common ground when participants shared in the joint experience of a task [42]. Unless the collaborative processes between doctors and patients is streamlined, the ultimate goals of patient-centered healthcare (respect; choice and empowerment; patient involvement in health policy; access and support; information) [43] will not be attained. In order to design HIT systems that address the unique collaborative needs of patients and doctors alike, there needs to be a better understanding of the barriers affecting doctor-patient collaboration. This research looks to bring doctors and patients together in a joint experience surrounding the hypertension task.

Future success with multi-faceted doctor-patient workflow integration is only possible when both doctor and patient lead-user requirements are collected and evaluated. Additionally, iterative design is necessary using evaluation methods that capture the perspectives, gains, and gaps at each workflow transformation. Eikey et al. conducted a systematic review of the role of collaboration in HIT over the past 25 years in their recent and comprehensive research [44]. The researchers compiled a list of 943 articles with HIT collaboration references; the compilation was further refined to 224 articles that were reviewed, analyzed, and, categorized. The study summaries a composite view into the key elements that affect collaboration in HIT with their Collaborative Space Model (CSM).

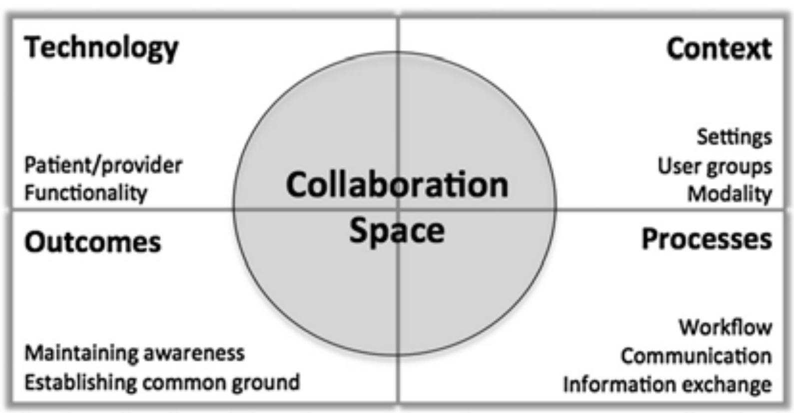


Figure 2: Eikey et al.'s HIT Collaborative Space Model

The CSM illustrates a foundational view summarized by the researchers as a starting place for future investigation into the critical dynamics of collaboration in HIT. The Collaboration Space Model (CSM) (as shown in Fig. 2) consists of four key components: (1) Context, (2) Technology, (3) Process, and (4) Outcomes. Although the CSM is a useful reference model for categorizing the various aspects of collaboration, based on a systematic HIT literature review, the model as not yet been field tested. Eikey et al. suggest that future research using the CSM should “focus on the expanded context of collaboration to include patients and clinicians, and collaborative features required for HIT systems” [44:274]. This research looks to build on the observations of Eikey and others in the HIT domain by conducting a live field test using the novel evaluation model and methodology introduced in this research.

Some HIT researchers and workflow integration experts have already investigated the use of VSM in the HIT space with promising results. It is my position that incorporating IE techniques such as VSM into the ethnographic process can deliver a unique evaluation perspective of all participants that complements other technology assessment methods.

Meaningful details regarding HT workflows, such as cycle-time and information quality at each step in the workflow, can be determined using a VSM process. VSM originated in Lean Six Sigma when companies such as Toyota were striving to reduce waste from manufacturing processes [45] [46]. VSM can be adapted to any software engineering workflows to identify waste or barriers to effective workflow [47].

VSM has been used to conduct workflow analysis in the healthcare industry [45] [48]. Incorporating the VSM approach in this research will help pinpoint specific areas in the HIT workflow that pose cycle time or information quality barriers. VSM will provide an over-arching workflow view that will help quantify acceptable time durations for each element of the workflow and the overall information quality requirements for doctor-patient collaboration within the HIT system.

The HIT domain is under immense challenge to manage this change, as identified and discussed in this section. To guide transformation in HIT, a consistent model and methodology is needed to evaluate the impact that new technologies have on collaborative efforts to existing HIT workflows, while illuminating the subtle requirements of both doctor and patient lead users. The aim of this research is to introduce a generalizable interdisciplinary model and methodology that can deliver important field information of end-user workflows that reflect the real-world requirements. Chapter 4 will introduce the Collaborative Space - Analysis Framework (CS-AF) that has been designed to address this need, and Chapter 5 will report on empirical case studies in the GC industry and the HIT industry using the CS-AF model and methodology.

1.6. Organization

This research is focused on the discovery, development, and comprehensive testing of a model and methodology (i.e., approach) to evaluate the association between the way individuals in a workgroup currently perform a work process (i.e., the current-state workflow), compared with the way they complete that same work process with the help of an enhanced technology-mediated workflow.

The focus of this research is to analyze related works in the collaborative workflow realm from a variety of disciplines (Chapter 2), to develop an integrated cross-disciplinary model and methodology to evaluate collaborative technology-mediated workflows (Chapter 3), to perform two comprehensive field tests from two diverse industry segments (i.e., graphic arts (Chapter 4) and health information technology (Chapter 5), and to validate the generalizability of the metrics and analysis methodology for the evaluation of technology-mediated collaborative workflows, compared with a current-state collaborative workflows. To demonstrate the functional use of the model and methodology, as well as to validate the approach for general use, two empirical studies of two diverse workflow scenarios are incorporated in this research.

1.6.1 CS-AF Summary of Metrics

The qualitative and quantitative data collection metrics and survey methodology are covered in detail in Chapter 3. The following summary provides a high-level orientation to the specific aspects of comparison and associated metrics incorporated in the CS-AF.

The CS-AF consists of five key interdisciplinary components that involve both qualitative and quantitative metrics: Context, Process, Technology, Attitude (and Behavioral Intent), and Outcomes. The Context of the workflows is characterized by seven attributes [17]. Each attribute has a range that can be expressed with a 7-point Likert scale (e.g., whether the workflow is synchronous, asynchronous, or mixed). Documenting the context of the workflow sets a foundational framework for how technology might enable different modes of collaboration.

The Process elements of the CS-AF are leveraged from the industrial engineering process improvements methodology of Value Stream Mapping [49], [50], or VSM. The process involves an analysis of the existing workflow by segmenting the major steps, and then measuring the time and quality output at each stage. The CS-AF incorporates a similar workflow analysis regimen documenting the critical time aspects of the current- and technology-mediated workflows. Quantitative time data and qualitative information quality data are recorded for this aspect of the CS-AF.

The Technology component of the CS-AF is a very important element in that the model and methodology seek to illuminate the value-add to the workflow from the introduction of technological improvements (infrastructure, interaction, and informatics). Technology adoption evaluation methods from the organizational management discipline have been integrated into the CS-AF, enabling both a quantitative data collection through user ratings (7-point Likert scale) and qualitative data obtained through targeted questions. This analysis enables a view of the significant vectors (such as the Perceived

Usefulness, Perceived Ease of Use, Ease of Learning, and Satisfaction) specific to each step in the workflow [22], [26].

The Attitude [22], [13] and Behavioral Intent [22] of users in the collaborative workflow is also incorporated into the CS-AF from the TAM and Net Promoter methods [27] that enable a qualitative perspective of the user's intention towards the workflow being analyzed. Are they open, interested, and engaged? Do they intend to use the workflow? Further quantitative data is collected using the Net Promoter scale to incorporate the element of promotion related to the workflow: How does the user feel with respect to promoting the workflow to others?

The final component of the CS-AF incorporates quantitative ratings evaluation of Outcomes (on a 7-point Likert scale) for each step in the workflow and leveraging CSCW [13]. This component of the CS-AF seeks to uncover the user's perspective with the alignment of their goals and information needs with those of others collaborating in the workflow. Additionally, qualitative questions are presented to provide further insights from workflow participants regarding the common ground and information quality across the entire workflow.

The workflow data collection and analysis performed using the integrated CS-AF is summarized for both the current- and technology-mediated collaborative workflows being evaluated, and the comparison of mean-data from both workflows is compared and contrasted in order to arrive at the final evaluation. Each workflow presents a unique set of process steps and test criteria. For example, the GC and HIT collaborative workflows incorporated in this research both have unique test criteria and a unique number of process steps; however, both workflow examples use the exact same CS-AF model and methodology. Comprehensive, detailed discussions of the Graphic Communications and the Hypertension empirical studies are in Chapters 4 and 5, respectively.

1.7. Summary

Included in this section is a case for a generalized cross-disciplinary approach to evaluate technology-mediated collaborative workflow utilizing the related works from four diverse and complementary domains. It is hypothesized that the cross-disciplinary integration of key collaborative workflow techniques and metrics would provide a robust and meaningful evaluation of a current-state workflow, compared to the enhanced technology-mediated workflow. The research utilized the Graphic Communication domain and my extensive experience to test the construct of the CS-AF and its merits for evaluating collaborative workflow. The research also proposed that similar collaborative workflow needs exist in other diverse domains where the CS-AF would be of value, namely, the Health Information (HIT) domain. The research proposed a second empirical study in the HIT for a hypertension doctor-patient collaborative workflow. Learnings from the first GC empirical study were assessed and incorporated into refinement of the CS-AF for use in the hypertension exam workflow.

The next section highlights related works in collaborative workflow evaluation and the formulation of the CS-AF, followed by the details of the CS-AF, its specific elements (i.e., Context, Process, Technology, Behavior, and Outcomes), and the cross-disciplinary specific determinants incorporated into the CS-AF. Details concerning the practical implementation of the CS-AF field methodology are also discussed.

Chapter 2

Related Work

2.1 Introduction

To thoroughly evaluate collaborative technology-mediated workflows, a multi-faceted view that incorporates a unique perspective from a variety of domains is essential. In many areas of science and engineering, cross-disciplinary research practice is becoming more common. Specialization in all areas of research, coupled with the need for advanced computing and engineering knowledge, has caused researchers to reach into other domains for collaborative support in order to explore and incorporate more far-reaching and connected research initiatives. Borrego et al. posit that cross-disciplinary research and education produce higher-quality results than do works from a single discipline; yet, admittedly, the effort is more time-consuming [51].

Jeffery states that those funding research should look to cross-disciplinary teams, frameworks, and methodologies to address complex research problems; …"Real world problems do not come in disciplinary-shaped boxes" [52:1]. Jeffery continues further to posit that cross-disciplinary efforts are mostly superficial, "edited summaries" and do not provide "genuine integration through collaborative working and common methodological frameworks" [52:2].

The literature reveals a variety of benefits of cross-disciplinary research, including expertise, expanded funding, experience, prestige, collaboration, and diverse perspectives, amongst others [53]. As much as there is a trend toward cross-disciplinary research, many efforts fall short of integrating cross-disciplinary methods in detailed ways that can be utilized beyond academia [54].

It is the aim of this research to investigate related works in collaborative workflow from several disciplines in efforts to not only understand the models, frameworks, and best practices, but more importantly, to integrate complementary elements into a robust and functional cross-disciplinary model with real-world applications. Specifically, this research will investigate the related works in the Social Sciences, Organizational Management, Human Computer Interaction/Computer Support-Cooperative, and Industrial Engineering, since these specific disciplines account for the largest concentration of related works in the area of collaborative workflow. This cross-disciplinary analysis of related works concerning collaborative workflow will be used to formulate a new integrated model and methodology in order to evaluate technology-mediated collaborative workflow in multiple domains.

2.2 Evaluating Collaborative Workflows in the Social Sciences

From a macro-perspective, the social sciences focus on the "study of human behavior and the societies we form" [55]. The three primary areas of the social sciences are the behavior and mental processes that affect behavior (psychology), the individual's relationship to society (sociology), and a generalized view and understanding of social phenomena (anthropology), amongst other sub-categories. This research is concerned with the collaboration of users interacting in a workflow that is enhanced by technology; therefore, the social sciences are of high interest and are directly related to collaborative workflow analysis. While a deep focus on cognitive psychology, group psychology, and cultural psychology is beyond the scope of this research, the behavioral intent and attitude of users associated with the workflow is a component of cognitive psychology that is directly related to this research. Further, the behavioral intent and attitude specific to the interactions within the workflow fall more directly into certain aspects of sociology (namely, work practice studies) and the approaches used to conduct field research in anthropology (namely, ethnography.) Therefore, this research looks at related works in the social sciences concerning the methods used by anthropologists to conduct work practice analysis using ethnographic techniques to determine behavioral intent and attitude toward work practices. Related works in the social sciences provide foundational building blocks and best practices that have been utilized in other disciplines and provide a key perspective for this workflow analysis research.

Ethnographic Studies of Work Practices

Ethnography is the observation of social phenomena in the social sciences. Over time, it has been attributed with number of associated terms, most of which are focused on the core notion of field observation. Such terms as “case study,” “qualitative inquiry,” “interpretive method,” and “fieldwork” are common terms used for ethnography [56]. "Ethnography literally means 'a portrait of a people.' An ethnography is a written description of a particular culture–the customs, beliefs, and behavior–based on information collected through fieldwork" [57:51].

From its origins in the early 1900's, the term, "ethnology," was used to describe the specific field study work of mostly western societies and cultures, compared with traditional culture. At that time, ethnology was the descriptive account of a community or culture and was seen as complementary to "ethnography." According to *The Dictionary of Social Sciences*, though, "over time, the term, 'ethnology' fell out of favor because anthropologists began to do their own fieldwork, with 'ethnography' coming to refer to an integration of both first-hand empirical investigation and the theoretical and comparative interpretation of social organization and culture" [55:1].

Over the past century, a variety of debates have surfaced regarding specific ethnographic methodologies and best practices for observation, field engagement, data collection, and data analysis. At a summary level, one of the most significant debates concerning ethnography is the contrasting approaches of positivism vs. naturalism. In short, the positivism approach to ethnography favors scientific process over an undisturbed natural-state observation of the naturalism approach. The positivism approach, according to Hammersley and Atkinson, "incorporates scientific theories that are open to test" [56:6]; this approach applies to a scientific methodology and experimentation that measures for both qualitative survey data and quantitative data from a statistical perspective.

The positivism approach is, of course, very important to ethnography, yet not completely in and of itself. The naturalism approach has less scientific rigor, but provides a means for a participant observer to uncover unique findings in undisturbed and the natural state of the target area. According to *The Dictionary of the Social Sciences,* "naturalism proposes that, through marginality, in social position and in perspective, it is possible to construct an account of the culture under investigation that both understands it from within and captures it as external to, and independent of, the researcher: in other words, as a natural phenomenon." [55:9]. For the naturalistic approach to ethnography, researchers take care to observe and record the undisturbed natural state, and to rely on the findings to direct conclusions and possible theories.

For certain, there is great virtue conducting field work with a scientific process, while simultaneously observing and recording phenomena in its undisturbed and natural state. To this end, Hammersley and Atkinson discuss the incorporation of reflexivity into the ethnographic mix as a means of integrating the strengths of these two opposing views (i.e., positivism and naturalism).

> Reflexivity refers to the process of reflecting on rather than just reflecting. The former is an active process, the latter passive. So, for example, in ethnography, the researcher is expected to be reflexive, i.e., to reflect upon the data gathered. Ethnographic reflexivity involves reflection on the impact of the researcher on the data. Reflexivity is usually regarded as central to all variants of ethnographic research [57].

Reflexivity incorporates two key principals: (1) the researcher must reflect on the research methodology in order to assess what effect that the approach may have had on the research, and (2) the researcher must reflect on the theoretical structures that come out of the research [57], [58].

Conducting ethnographic work practices research with a scientific methodology to observe the user of a workflow in the natural state, while incorporating the principles of reflexivity, is a complementary element of this research. This important contribution from the social sciences domain fortifies the methodology and goals of this research towards a generalizable model to observe and to analyze collaborative workflows in multiple domains. The integration of reflexivity into ethnographic practice enables a closed-loop process for semi-structured field engagement, based on theoretical process that iteratively informs the next field engagement [59].

Incorporation of the ethnographic approach is a foundational component of this research, and the subsequent model that has been developed leverages this approach. Ethnographic field work captures valuable user experience data that can be instrumental in directing technology development. The ethnographic process, however, is quite broad–ranging from undisturbed natural observation to a more structured process. Undisturbed ethnographic research in the natural setting yields an enormous about of information, yet is difficult for the research to coalesce and analyze. Structured ethnographic research yields more targeted data, yet sacrifices some of the spontaneity of undisturbed research. For this research, the focus is on a specific work practice tasks (i.e., GC Sales Quotation workflow and hypertension blood pressure workflow). The field observation and interaction was directed by the logical pre-defined steps in the task or workflow that provided the appropriate ethnographic structure. For each case study, logical workflow steps were defined; the research engaged users with semi-structured observation, and structured and unstructured questions associated with each step in the workflow and the overall workflow experience. A further look into related works in other interdisciplinary domains shows that ethnographic research is a well-accepted and adaptable methodology that can deliver meaningful data.

Goulden et al. posit the importance of ethnographic research in computer science. [60]. This research team conducted ethnographic research associated with technology-mediated collaboration from a case study on Public Access Wi-Fi Services (PAWS). The team was composed of computer scientists and sociologists who worked together to observe the adoption of WI-FI digital technology workflow within a marginalized community. The ethnographic process uncovered valuable insights associated with the workflow, and more importantly, with the ethnographic process utilized. Of specific interest to this research are the learnings from the ethnographic methods in the technology-mediated workflow. The research identified a variety of problems, such as time-consuming interactions with acquiring a desired number of test subjects and technical support issues with Wi-Fi connectivity. These infrastructure issues could be resolved with more streamlined technology. However, other issues were uncovered; these issues were associated with the interest and willingness of the test subject to engage in the workflow, stemming from poor assumptions about the unmet needs and wants of the target test group. Further complicating this test scenario was the convoluted flow of requirements associated with the technology-mediated collaborative workflow. The baseline assumption that a marginalized population would want or need Wi-Fi was a flawed assumption, and the research became more of a technology push than a desired solution. Furthermore, conducting ethnographic research without an appropriate baseline sets up the engagement for risk and ambiguity. Without an established problem to solve, or a substantiated need and a baseline on the current-state workflow, researchers were left to iterate and implement without a target goal, nor a quantifiable measure of what success will be when it was achieved. Finally, as the research lacked a mechanism to capture the behavioral aspects of adoption simultaneously with the technical aspects, the researchers shared that future work should incorporate a means of collecting both aspects of technology adoption.

Peneff suggests that ethnographic researchers need to cope with the ad hoc nature of field settings by "formalizing tasks in a manner naturalistic enough that the human participant might engage as if it was a conversation with a trusted acquaintance" [61:520]. This research aligns with Peneff by establishing a structured approach for ethnographic research that is directed by the specific workflow steps required to perform a task. This research also introduced the novel concept of incorporating a more formal baseline evaluation and measurements of the existing workflow, and behavioral perspectives of test subjects prior to the technology solutions as a means to address the ambiguous nature and associated problems that arose in the PAWS case study.

It is important for the success of this type of research to focus on substantiated needs that are holistically recognized by a community. Ellsworth-Krebs et al. [62:100] express that, for ethnographic work to be successful, there needs to be a "technological solution to a social problem," not a technology push, as in the case of the PAWS study. The ethnographic focus must be "through the eyes of the members in the setting, not the technologist" [62:100]. The aim of this research was to incorporate ethnographic methods, amongst other techniques, to uncover the association between the existing workflow and the technology-mediated workflow, specifically for a clearly identifiable problem and for a community that already identifies with this problem and is actively seeking a solution to these needs and wants associated with the problem workflow.

Behavioral Intent and Attitude in Work Practices

Another branch of the social sciences, sociology, the study of individual's relationship to society [63], [64], [65] is of particular interest to this research, specifically in regard to the study of work practices. Sociologists researching work practices often look at the behavioral intent and attitude associated with workers while performing their work, both of which are integral elements to consider in the transformation and adoption of new technology-mediated workflow. Sociologists evaluate, amongst other aspects, the attitude of workers toward the work that they are doing. Are the users' content with the work processes they need to use in order to produce the work? Behavioral intent is another aspect of work practice research that sociologists investigate. Are the workers motivated to use the workflow provided? Do they have the intention to use, or to avoid, the workflow? Evaluating the attitude and behavioral intent of users attempting to perform work using a specific workflow is an important aspect of this research, and it has been pivotal in other related works. Ajzen defines behavior "as an observable act, is related to the individual's persuasive or attitudinal feelings; whereas attitude/attitudinal feelings are defined as the degree to which a person has favorable or unfavorable evaluation or appraisal of the behavior in question" [66:188].

The social sciences are steeped in research involving the interplay between attitude-behavior relations as evaluated with respect to an entity, which for the purposes of this research, is the work process. In a comprehensive theoretical analysis by Ajzen et al. on attitude-behavior relations, the researchers identify the tricky association between attitudes and behavior, and provide some very helpful guidelines based on empirical data from prior research [67].

Ajzen et al. point out that two important questions can be identified with research involving attitude-behavioral relationships: (1) What are the entities of the attitudinal predictors and the behavior criteria? (2) What is the degree of correspondence between the attitudinal and behavior entities [67]? For this research, the entities will be consistently defined as the specific work steps involved in the work process (i.e., workflow) that are followed exactly by all workers/users towards the goal of completing the specific work task. There is also a direct correspondence between the attitude and behavior of each worker/user towards completing each step in the workflow, as well as completing the overall workflow task.

Ajzen et al. further establish four different elements from which attitudinal and behavior entities may be evaluated: "the <u>*action*</u>, the <u>*target*</u> at which the action is directed, the <u>*context*</u> in which the action is performed, and the <u>*time*</u> at which it is performed" [emphasis theirs] [66]. These four evaluation elements (action, target, context, and time) establish a consistent framework from which to observe, collect data, and evaluate the relationship between attitude and behavior. The researchers found a high correlation between attitude and behavior, specifically when there was both a direct correspondence between attitude and behavior, and when the four elements of evaluation were consistently defined. The researchers suggest that "to predict behavior from attitude, the investigator has to ensure high correspondence between at least the target and action elements of the measures he employs" [66:188].

This research is aimed at the development of a generalizable model and methodology to evaluate an existing workflow and a technology-mediated workflow and, therefore, lends itself to a structured view of each specific task leading to the completion of the workflow and an associated measure at each step of the way. Establishing a baseline view of the workflow from several vantage points, and then capturing an updated view of the same workflow with the new technology-mediated improvements, enables a meaningful comparison and respects the research principles suggested by Ajzen et al. [66] [67] [68].

2.3 Technology-Mediated Collaborative Workflow Adoption in Organizational and Behavioral Management

The organizational and behavioral management discipline has long been interested in research associated with the adoption of technology and the way that technologies are assimilated into the workplace and integrated within existing work practices and workflows. Organizational and behavior management researchers have incorporated an interdisciplinary approach to develop reference models that establish a consistent approach to the discovery and analysis of technology-mediated workflows. Ajzen and Fishbein were first to incorporate behavior as a measure in their model, the Theory of Reasoned Action (TRA) [67]. The TRA was an instrumental in the development of the widely-adopted Technology Acceptance Model (TAM).

Uncovering insights into technology adoption and how technology-mediated workflows can increase productivity is key to establishing and maintaining a competitive advantage for enterprises. The study of technologies in the organizational and behavioral management field tends to be focused on two primary areas of targeted research: individuals and their reaction to technology within the workplace, and the organization’s response to technology as a whole. [68].

In an effort to characterize the way individuals and organization react to the introduction of new technology in the workplace, a number of technology adoption assessment theories and models have been developed over the years. Table 1 provides a date-ordered list of the predominant technology adoption assessment theories and models, and distinguishes which are most suited to research associated with individuals and those which are more associated with organizations [69] [70] [71].

Technology Adoption Theory, Model	**Researcher(s)**	**Date Published**	**Focus: Individual vs. Organizational**
Task-Technology Fit (TTF)	Strong, Deshaw and Bandy	1973	Individual
Theory of Reasoned Action (TRA)	Fishbein and Ajzen	1975	Individual
Theory of Planned Behavior (TPB)	Ajzen	1985, 1991	Individual
Technology Acceptance Model (TAM)	Davis, Bogozzi and Warshaw	1989	Individual
Technology Organization Environment (TOE) framework	Tornatzky and Fleischer	1990	Organization
Innovations Diffusion Theory (IDT)	Rogers	1995	Organization
Decomposed Theory of Planned Behavior (TPB)	Taylor and Todd	1995	Individual
Technology Acceptance Model 2 (TAM2)	Venkatesh and Davis	2000	Individual
Unified theory of Acceptance and Use of Technology (UTAUT)	Venkatesh	2003	Individual
Technology Acceptance Model 3 (TAM3)	Venkatesh and Bala	2008	Individual

Table 2: Technology Adoption Assessment Theories and Models

For this research, the focus is on individuals and their specific interaction with the technology-mediated workflow in the context of a defined work process; therefore, the focus of this research is not on related works that emphasize overall organizational impact. Both the Technology

Organization Environment Theory (TOE) of Tomatzky and Fleischer [72] [73] and the Innovation Diffusions Theory of Rogers (IDT) [74] have an organization focus and, thus, were not used in this research. The Technology Organization Environment Theory (TOE) [72] [73] evaluates the technological, organizational, and environmental contexts that influence technology adoption across the firm [69]. The Innovation Diffusions Theory (IDT) [74] assesses the ways in which individuals and organizations assimilate technological innovation over time or diffuse the technologies into their routine practice [71]. Both the TOE and IDT approaches have been effectively used to evaluate organization-wide characteristics regarding technology adoption, yet the most predominantly used models for the evaluation of technology adoption by individuals in the organizational behavior and management arena are the Technology Acceptance Model (TAM) [22] and derivatives of the TAM. This research explored the TAM further to investigate possible points of synergy for evaluating a technology-mediated collaborative workflow, including areas for possible improvement that might make the TAM a more effective model.

Prior to the introduction and adoption of the Technology Acceptance Model in 1989, several other models had been introduced with varying degrees of success: the Task-Technology Fit Model [75], the Theory of Reasoned Action [76], and the Theory of Planned Behavior [77].

The Task-Technology Fit Model [75] evaluates the impact that technology has on an individual to determine if there is a good technology fit. Goodhue et al. posit that a good technology fit delivers positive impacts to an individual with improvements in efficiency and effectiveness associated with a task, increasing the likelihood that the technology will be utilized or adopted. The TTF model can be effectively used to research the adoption and utilization of new technologies introduced into the marketplace. Goodhue et al. suggest that the TTF model falls short in its ability to adapt and represent a variety of tasks: “Refining the existing TTF dimensions, or expanding to focus more on user tasks, are both potential areas for improvement" [78:230]. Additionally, Goodhue et al. suggest that developing "some standard set of measurable dimensions for use in comparing information" would be important future work [78:231].

From the seminal works of social scientist Martin Fishbein, who pioneered theories that explain and predict social behavior of humans, emerged the first theoretical framework in technology adoption to be widely accepted: The Theory of Reasoned Action (TRA) [76]. The TRA was successful in using attitudes as a means of explaining and predicting behaviors. As illustrated in Fig. 3, TRA posits that individuals will use a specific technology when they can see a positive outcome, or benefit, associated with the use of that specific technology [79].

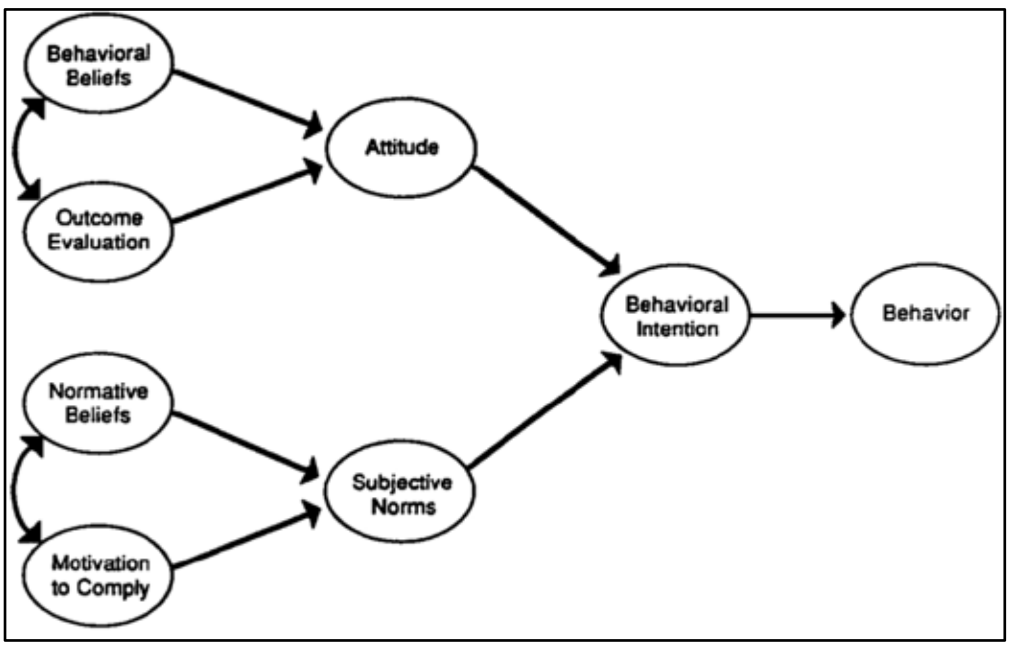


Figure 3: Fishbein & Ajzen's Theory of Reasoned Action

The original application for the TRA was confined to "behaviors over which people had volitional control," since both Fishbein and Ajzen assumed this focus was inclusive of most of the types of behaviors that social psychologists were concerned with. The assumption was, however, not valid, as it “imposed severe limitations on a theory meant to explain and predict all kinds of socially significant behaviors” [79:14].

From his research efforts on the TRA and the knowledge gained about strengths and limitations of the TRA towards behaviors, Ajzen expanded the breadth of the TRA to form the Theory of Planned Behavior [66].

The Theory of Planned Behavior expands on the attitude and subjective norms of the TRA to include a third facet of behavior, perceived behavioral control (as shown in Fig. 4) [66]. The addition of this predictor to the TPB model provides an element of self-efficacy [80] that addresses the perception of the degree of control that individuals feel may limit their behavior [79].

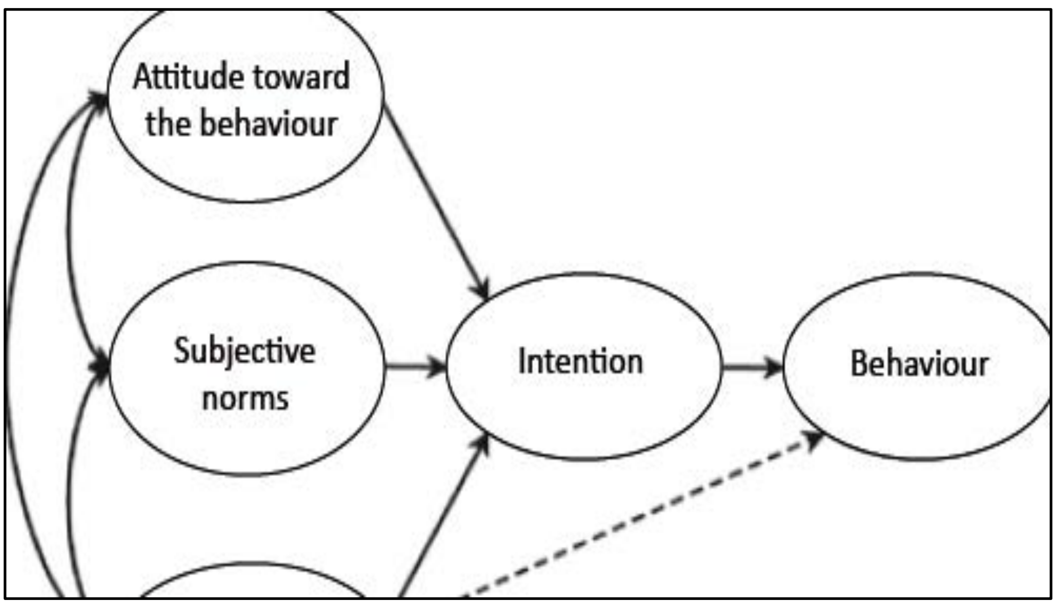


Figure 4: Ajzen’s Theory of Planned Behavior

Since the introduction of the TPB in 1991, many researchers have used this theory/model to effectively evaluate behavior that is guided by intentions. The TPB assumes a strong and perpetual correlation between intentions and behavior, and assumes that this association will remain intact over time, such that “changes in intention are followed by changes in behavior” [79:18]. Some areas for improvement and expansion to the TPB may be that an “expansion of the TPB in order to further describe the relationship of intentions to behavior may provide a useful way to develop the TPB in relation to understanding how attitudes impact on the achievement of goals” [81:1453]. A second possible expansion for the TPB may be “understanding how goal intentions are translated into actions and goal achievement” [82:501].

The Technology Acceptance Model [8] was developed from an adaptation of the TRA; it was the first model to incorporate psychological predictors that affect technology adoption and acceptance of individuals. Davis initially used the TAM to evaluate technology-mediated adoption of computer systems by individual users. Foundational to the TAM are two key determinants that Davis believed are essential to user motivation. The first is concerned with the value that a user perceives the technology will deliver. “People tend to use or not use an application to the extent they believe it help them perform their job better” [22:320]. This first determinant, Perceived Usefulness (PU), is a predictor in the TAM aimed at evaluating the utility that a certain technology-mediated system provides a user. The second determinant in the TAM composing user motivation, Perceived Ease of Use (PEU), is associated with how easy the technology is to use, or "the degree to which a person believes that using a particular system would be free of effort” [22:320] [83]. Fig. 5 illustrates Davis’s original model.

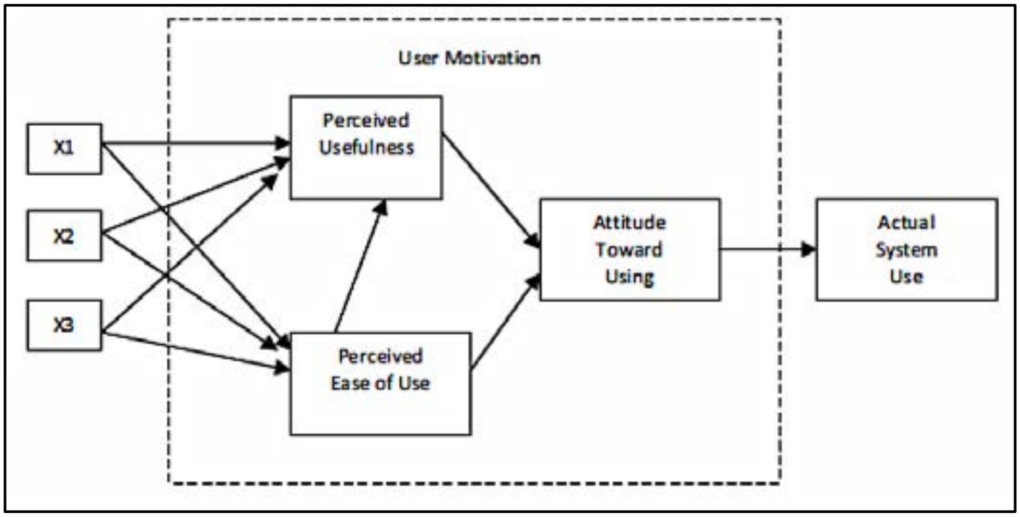


Figure 5: Davis's Original TAM

Davis believed that these two determinants, Perceived Usefulness (PU – enhancement of performance) and Perceived Ease of Use (PEU – freedom from effort), are the essential elements of technology acceptance, and when coupled with a view of the user's attitude toward using the technology, provide a parsimonious and functional model that can deliver a meaningful evaluation of technology adoption.

The revised TAM was refined to include consideration for other factors, or external variables that might influence users [84]. In addition, the user's attitude towards use and behavioral intention to use were incorporated into this revised TAM to represent behavioral components associated with user adoption. The final version of the TAM (as shown in Fig. 6) was refined further, modifying "Attitude Towards Use" to "Behavioral Intention" and changing "Intention to Use" to "Usage Behavior" [85].

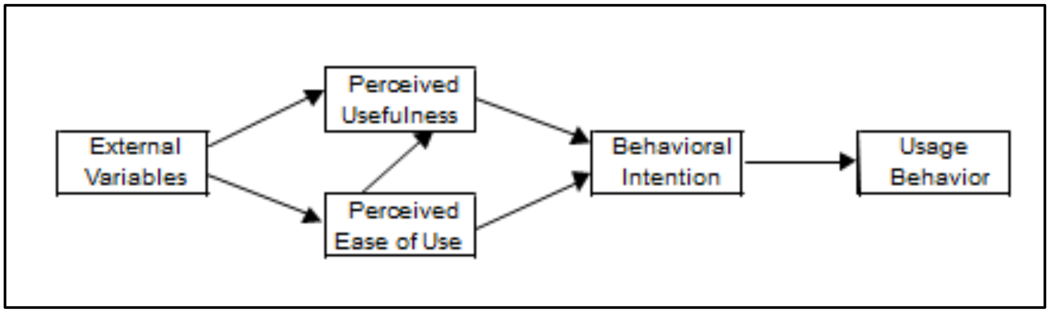


Figure 6: Davis & Venkatesh's Final Version of the TAM

The TAM is historically the most widely used model by researchers for technology acceptance and adoption of users across a multitude of disciplines. Foundational to the TAM methodology is the survey instrument which contains fourteen questions surrounding the Perceived Usefulness (PU) construct and fourteen questions associated with Perceived Ease of Use (PEU). Davis determined that asking a minimum of ten questions for each perceptual variable (PU and PEU) would achieve reliability of at least 80%, and that using fourteen questions for each construct would provide for the potential elimination of items with indeterminant response [22].

The TAM is easy to understand and deploy, and it can be adapted with other attributes that deliver complementary determinants [86], [87]. The first modified version of the TAM was proposed in 2000, also by Davis and Venkatesh, to address two primary areas: (1) to introduce new determinants and to uncover social influences and "cognitive instrumental processes" and (2) to provide a view at specific time intervals that are meaningful to users associated with determining technology acceptance [88]. The notion of conducting a time view at key intervals of adoption is of particular interest to this research. In TAM 2, Davis and Venkatesh evaluate 3 time intervals (pre-implementation, one-month post-implementation, and three-months post-implementation.) This approach provides a valid snapshot, yet it does not go far enough to establish a quantitative baseline measure that can be easily compared in a complementary sense with the qualitative survey questions [23]. It is my belief that there is an opportunity for improvement to the TAM with more rigor in the time-interval evaluations using techniques from industrial engineering, such as Value Stream Mapping (VSM). VSM and the connection to technology adoption and acceptance are discussed in the next section.

With respect to the addition of new determinants introduced in TAM 2 (to uncover social influences and cognitive instrumental processes), and although these additions provide more user insight than do the original TAM, they are by no means comprehensive of all the variables that might influence user adoption (e.g., social, organizational, environmental, and cultural.). In Bagozzi's critical review of the TAM, social influences "can be important influences on decision making, but it is important to recognize that they apply to a limited sense of social behavior, i.e., that are related to interpersonal influence and all too often treated in a largely unidirectional sense; empirical research with TAM in this regard has found either mixed results or evidence for social influence in only restricted contexts" [89:247].

The TAM 2 was further expanded to form the TAM 3 [90] and, later, the Unified Theory of Acceptance and Use of Technology (UTAUT) was formed [23]. Both the TAM 3 and UTAUT add categories of external variables that drive user influence. For TAM 3, the authors integrated TAM 2 and four determinants (i.e., individual differences, system characteristics, social influence, and facilitating conditions) of Perceived Ease-of-Use/Perceived Usefulness [90]. The UTAUT expands further on the TAM 3 to incorporate moderating variables (i.e., gender, age, experience, and voluntariness of use) that can the influence of the four independent constructs (i.e., individual differences, system characteristics, social influence, and facilitating conditions) on behavioral intent and usage behavior [89]. Fig. 7 shows the original UTAUT model.

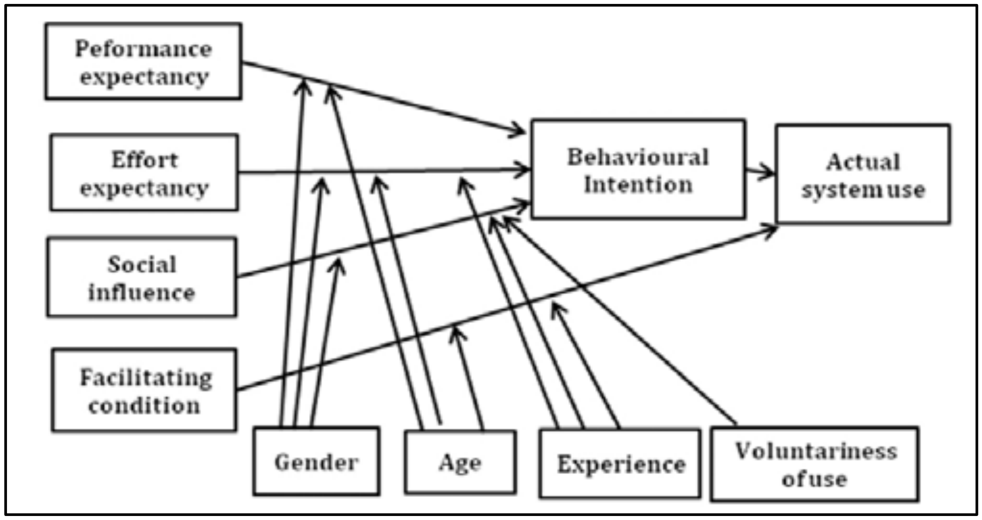


Figure 7: Venkatesh et al.'s UTAUT Original Model

In efforts to preserve the parsimony of the original TAM, adding determinants for all possible external variables does not seem practical; rather, an adaptation of the original TAM that includes a more generalizable way to capture a snapshot of the context for the technology, environment, and users in review seems more realistic. The notion of context, including an approach to incorporate valuable context parameters into the generalizable model, will be explored in the Human Computer Interaction (HCI) section.

The TAM provides a parsimonious model that can be adapted to a variety of research settings to uncover meaningful insights regrading technology adoption. The TAM proves as an ideal starting point for this research, assuming that certain modifications can be made to enhance the effectiveness and generalizability of the model, while maintaining a high degree of parsimony. The TAM can be carefully expanded to address a better view of the context and setting of the technology assessment, as well as to provide more definitive baseline information about the time involved in the pre- and post-implementation stages (or the current-state vs. the technology-mediated collaborative workflow). Further, critics of the TAM also believe that putting too much weight on external variables and behavior intentions, and not giving enough consideration towards user goals in the acceptance and adoption of technology, is a limitation of the TAM in all its forms [89]. Incorporating provisions to acknowledge user goals would also be possible areas for improvement to the TAM.

The TAM was originally developed to evaluate technology acceptance for word processing [22] and, since then, has been used for many technology evaluations. It has also been adapted and used in a variety of industry segments where technology is a driver, including information technology (IT), manufacturing, management information systems (MIS) system, and health information technology (HIT), amongst others. Davis et al. state that the "goal of the TAM is to be capable of explaining user behavior across a broad range of end-user computing technologies and user populations, while at the same time, being both parsimonious and theoretically justified" [22].

Yousafzai et al. conducted a two-part meta-analysis of the TAM which reviewed 145 papers on the TAM, covering a range of technologies from "acceptance e-mail, voice mail, graphics (Adams et al., 1992), DBMS (Szajna, 1994), GSS (Chin and Gopal, 1995), personal computer (Igbaria et al., 1995b), WWW (Gefen and Straub, 2000), and tele-medicine technology (Chau and Hu, 2001), among other applications of IT" [24:253]. Yousafzai et al. further state that the popularity of the TAM is summarized in its three attributes: (1) it is parsimonious, yet versatile, for a broad range of technologies and populations, (2) it has a strong theoretical base and psychometric measures, and (3) it features strong explanatory power and accumulated empirical support [24], [25].

In the second part of the TAM meta-analysis, the authors discuss some of the weakness of the TAM and suggest areas for improvement. Yousafzai et al. suggest that the TAM has showed a weaker predictive capacity in Japan vs. the US and may pose unique cultural dimensions that should be taken into account surrounding the context of the technology analysis [24], [25]. Attitude may not be as strong a determinant in a mandatory setting where users are required to adopt the technology being evaluated. In such a mandatory setting, users essentially have only two choices (other than leaving the organization): accept the innovation wholeheartedly or accept it begrudgingly. Users in the latter category are likely to delay or obstruct the implementation, and resent, under-utilize, or sabotage the new system [24].

Yousafzai et al. also posit that usage poses a potential issue for the TAM with many examples of the TAM using self-reporting data; "… 47 per cent of the studies measured self-reported usage, less than 9 per cent measured the actual usage" [24:253]. The authors seem to believe that the "lack of task-focus in evaluating technology" has led to some mixed results. They further suggest that an opportunity to incorporate usage models for the TAM may strengthen predictability; yet caution is needed to manage model complexity [24], [25]. The question of usage and use models directs the focus of this research towards the field of industrial engineering for related works surrounding the research usage of workflows.

2.4 Evaluating Technology-Mediated Collaborative Workflows in Industrial Engineering

Foundational to technology adoption and acceptance is the promise of technology-mediated improvements that promise either a more efficient way to perform a known task or the introduction of a new feature that was previously unavailable. In either instance, technology-mediated innovation is aimed at new way to optimize a task or process, whether new or existing. Industrial

Engineering emerged as a discipline in the late 18th and early 19th century when Frederick Taylor published his theory of scientific management [91]. Taylor developed scientific methods and tools to accurately analyze human labor [92]. A number of other key contributions [91] [93] to what is now the industrial engineering discipline were also introduced in that era. Amongst others, they are:

- Introduction of the assembly line, Samuel Colt, 1847 [94]
- Process Improvement Methodology, Harrington Emerson, 1902 [95]
- Gantt Chart for Organizational Management, Henry Gantt, 1912 [95]
- Assembly line for automobile manufacturing, Henry Ford, 1913 [97]
- Theory of Constraints, Eliyahu M. Goldratt, 1985 [98]

The Handbook of Industrial Engineering [99] states that the mission of industrial engineering is "achieving full potential…[of a] system" (whatever that system is) and that the means to achieve full-potential of any system comes from incorporating Lean principles into the process. A simplification of the Lean process is contained in three words, Plan > Do > Act, and uses this approach: (1) establish organizational/system goals, (2) evaluate or assess of the current-state of the process, (3) determine the future-state goals and objectives, (4) implement the plan, and (5) analyze results and plan for next cycle [99].

Central to the industrial engineering (IE) discipline is a focus on Lean process improvement which strives to find ways to perform tasks in the most optimized manner. The term, "Lean Six Sigma," refers to the integration of Lean methodologies into the elimination of waste via Six Sigma methodologies to reduce process variation. "Lean exposes sources of process variation and Six Sigma aims to reduce that variation enabling a virtuous cycle of iterative improvements towards the goal of continuous flow" [100:41].

The Lean vision is centered on the value stream, or the workflow associated with completing a specific process, needed to perform a task [101]. Through Lean process improvement, the value-add and non-value-add (i.e., waste) aspects of a work process are identified, and all waste (*muda*) is targeted for elimination [102]. Lean Six Sigma can be described as "a well-structured theory-based methodology to improve performances, develop effective leadership, customer satisfaction and bottom-line results" [103:3]. Eight types of waste are identified in the Lean methodology as defects, over-production, waiting, non-utilized labor, transportation, inventory, motion, and extra-processing [100].

Of specific relevance to this research is the method used by IE to uncover the task details that are weakly defined in the TAM [24], [25], in efforts to add more precision to the time and quality calculation associated with each major step in the workflow and the overall completion of the work process task. The methodology used by IEs to collect data and analyze the current-state/future-state workflow is VSM [46], [103].

VSM originated in Lean Six Sigma with firms such as Toyota striving to reduce waste from manufacturing processes [46], [103], [104]. VSM can be adapted to software engineering workflows to identify waste or barriers to effective workflow [105]. VSM establishes a common language and procedural methodology for characterizing a process or workflow in a quantitative manner, such that each step in the workflow is identified and measured. VSM involves four steps: identifying the workflow scope, current-state drawing, future-state drawing, and work planning implementation [105]. It is my belief that the VSM process can be adapted for use in a generalized model to establish a technology acceptance baseline (time/task analysis) of a pre-implementation or current-state workflow, and then repeated with the technology-mediated implementation (future-state) for analysis and evaluation of the gain.

The VSM process is largely a pen-to-paper exercise for recording the process, steps, time, and quality deficiencies in a workflow, although there are VSM software tools designed to streamline the process (e.g., eVSM and VLSAT) The VSM elements of specific interest to this research are (1) time (cycle time: duration of task from start to completion, and lag time: idle time between tasks) and (2) information quality (accuracy and accessibility of information entry and retrieval). By identifying each significant step in the workflow, and collecting the time and quality data, a value stream map can be created indicating the total time for the workflow and identifying all quality issues throughout the process. When VSM is used in conjunction with technology-mediated improvements, the current-state workflow details can be compared with the future-state to uncover process gaps and gains [47], [48], [105]. The VSM generates a process-and-flow view of the workflow steps and quantification of times for each workflow step (cycle time), idle time (lag time), and total process time, including an indication for quality issues throughout the workflow. Fig. 8 illustrates the VSM process.

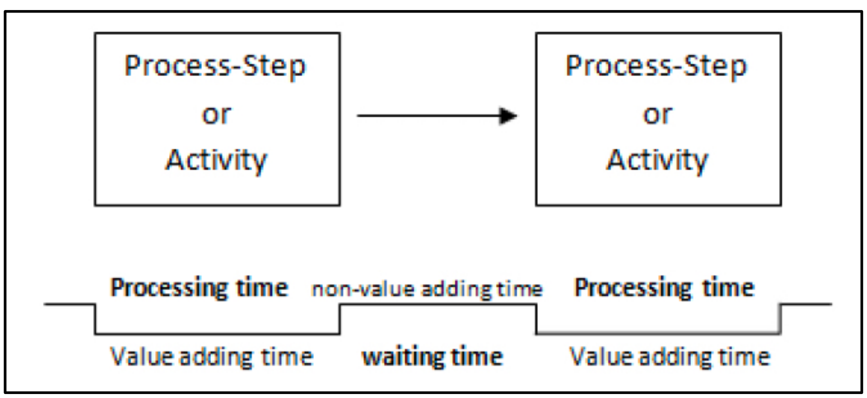


Figure 8: Value Stream Process

VSM has been successfully used to conduct workflow analyses in a variety of industries, including telecommunications, manufacturing, information technology, and healthcare [47], [48], [105], [106], [107], [108], [109], [110], [111].

Incorporating the VSM approach in this research helped establish a baseline from which to compare the cycle-time or information gaps and gains of a technology-mediated implementation, with specific reference to the pre-implementation context. Using VSM, in association with a modified version of the TAM, also fortified the TAM with precision and rigor associated with the very specific task identification for a given workflow or task [24], [25]. VSM provided an over-arching workflow view that helped to quantify time durations and the overall information quality requirements for each element of the workflow [109], [110].

2.5 Evaluating Collaborative Technology-Mediated Workflows in Human-Computer Interaction (CSCW/HCI)

Since the inception of computers, researchers have passionately investigated the interaction between humans and computers; this evolving interplay is core to realizing the ever-increasing potential of both humans and computers. With computing becoming mainstream in all aspects of our professional and personal lives, the need for advanced insights into the seamless human-computer connectivity through more capable and intuitive interfaces has become paramount. The term, "human-computer interaction," (HCI) was coined in 1980 by Card, Moran, and Newell, and gained popularization as a term and as a discipline through their historic book, *The Psychology of Human–Computer Interaction* [112].

HCI is defined as "a discipline concerned with the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" [113:5]. Central to this research is the evaluation aspect of the HCI as it relates to the collaborative efforts of two or more individuals in a workflow aimed at completing a specific task. The HCI discipline is charged with "immersive understanding of the ever-evolving tasks and artifacts" [114] and, therefore, related works in HCI enhanced this research with unique perspective to evaluate possible gains and gaps that the technology-mediated computing systems deliver to the collaborative workflow experience [115].

In 1984, the term, "computer-supported cooperative work" (CSCW), was coined by Greif and Cashman [1] to focus on the "understanding of the way people work in groups with enabling technologies" or technology-mediated workflows. CSCW has historically worked through an interdisciplinary approach to integrate the academic fields of computer science and social sciences with a design-orientated focus on the role of technology in collaborative computing systems. CSCW is concentrated on the social-technical gap between humans and computers from an exploratory and implementation perspective [116].

A notable pioneer in technology-mediated collaborative workflow research, pre-dating the formation of HCI and CSCW, was Douglas Engelbart, who won the prestigious ACM Turing Award for his seminal work on interactive computing. Engelbart's innovation in the area of a communications-based working environment included an integrated view of revolutionary computing technologies well before any commercial presence.

> Dr. Douglas C. Engelbart is a true pioneer, where he established an unparalleled track record in predicting, designing, and implementing the future of organizational computing well before human computer interaction was even recognized as a field. From his early vision of turning organizations into augmented knowledge workshops, he went on to pioneer what is now known as collaborative hypermedia, knowledge management, community networking, and organizational transformation. Well-known technological firsts include the mouse, display editing, windows, cross-file editing, outline processing, hypermedia, and groupware. [117]

Both the HCI and CSCW disciplines provide an enormous volume of valuable research contributions and perspectives in the technology-mediated collaborative computing space. This research highlighted related works from both disciplines intermixed, acknowledging that there are unique differences between the two closely-related disciplines. HCI research is driven from a cognitive science perspective, while CSCW is driven from the natural friction between social-technical relevance [116]. In either case, whether for HCI or CSCW, both disciplines strive for deeper understandings of the optimal interaction between human and computer. Related works for this research focused on aspects of HCI and CSCW that explore effective ways to evaluate and analyze collaborative workflows using enhanced technology-mediated computing systems.

From the onset, early HCI research was concerned with the "total performance of the combined user-computer system, [including]… the psychological characteristics of users and their interaction with the task and the computer" [113:7]. In this research, Hewett et al. posit that both qualitative and quantitative metrics are necessary when evaluating a technology-mediated collaborative workflow, and they introduce a method to measure the task-time as a complement to other psychological factors [113]. Hewett et al. developed a "keystroke-level model for user performance time with interactive systems" that enabled them to capture quantitative time data related to users and tasks. This time data was then compared to the performance time of an expert user (baseline) and other users. The researchers posit that "many other important aspects of performance" need to be included for a robust and generalizable model [118:409]; however, it is my belief that including time measures with other design attributes can be a valuable complement to qualitative measures.

CSCW strives to incorporate a wide terrain of interdisciplinary interests, and therefore, establishing a single generalizable model to evaluate "collaborative activities and their coordination" [115] has been difficult. Historically, CSCW tends to focus on qualitative research guided by frameworks with varying degrees of flexibility. Neal et al. suggest that there are three types of CSCW frameworks that emerge from CSCW research: methodology-oriented, conceptual, and concept-oriented. Each CSCW framework type has a valuable focus, but no single framework addresses the full range of CSCW needs [13], [119].

In efforts to attempt a generalizable framework to evaluate collaborative workflow, this research is constrained specifically to technology-mediated collaborative workflows (of two or more people) with a shared goal of completing a specific task. This aligns with Grudin's definition of CSCW as "small groups usually consisting of 2-3 people who work together to reach a common goal" [1]. With this concentration in mind, this researcher posits that CSCW framework principles can be integrated to represent both qualitive and quantitative evaluation.

Grudin introduced the Conceptual Collaboration Model (shown in Fig. 9) in an attempt to help CSCW researchers visualize the hierarchal representation of groupware from the individual to the small group and the organization [1].

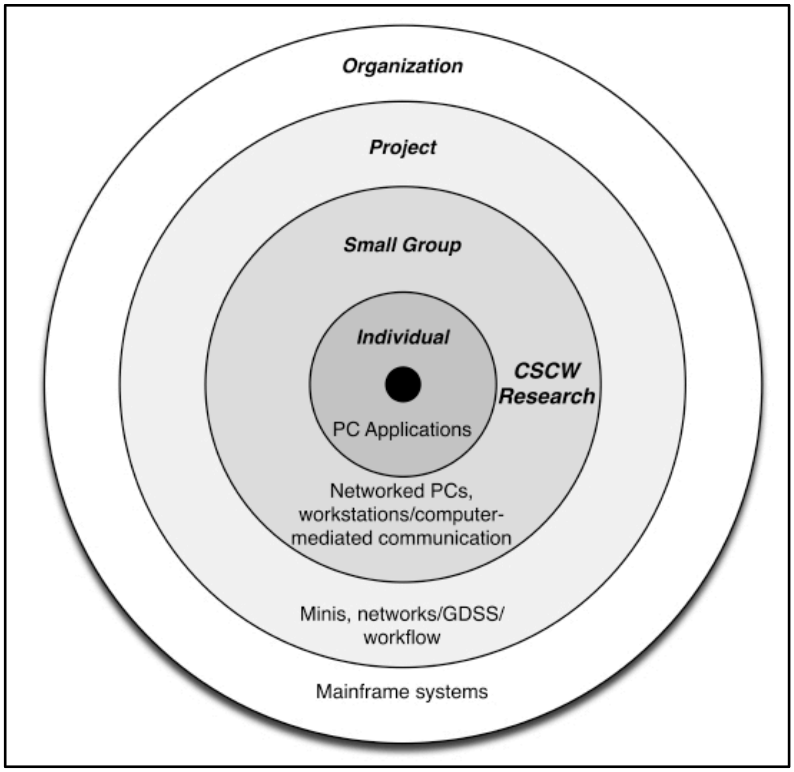


Figure 9: Grudin's Conceptual Collaboration Model

CSCW research is also focused on the "study of tools and techniques of groupware, as well as their psychological, social, and organizational effects [120:3]. Core to CSCW and HCI research is determining the context of the target cooperative computing system. Johansen's Time-Space Collaborative Context Model (shown in Fig. 10) is used by many in HCI to conceptualize the context for the cooperative workflow–whether remote/co-located or synchronous/asynchronous [121].

	Time	
	Synchronous	*Asynchronous*
Face-to-face meetings	1. Facilitation services 2. Decision support 8. Beyond white board 17. Nonhuman participants	4. Presentation software 5. Project management 14. Memory management 16. Comprehensive support
Electronic meetings	3. Telephone extension 9. Screen sharing 12. Teleconference aid 15. Spontaneous interaction	6. Calendaring 7. Group writing 10. Computer conferencing 11. Text filtering 13. Conversation structuring

Figure 10: Johansen's Time-Space Collaborative Context Model

CSCW and HCI involve the integration of many unique disciplines; therefore, accurately framing the environment and conditions associated with the targeted cooperative work is necessary for a precise evaluation [16], [122]. Millen states that "understanding the context of the user environment and interaction is increasingly recognized as a key to new product/service innovation and good product design" [16:285]. CSCW and HCI conceptual models help researchers formulate a framework to describe a particular context in focus [123].

Neale et al. posit activity awareness as an overarching concept to describe a comprehensive view of collaboration from the activity perspective [13], [119]. Their research introduces the Activity Awareness Model as a conceptual framework aimed at representing the key variables that one should consider when evaluating distributive computing applications. Fig. 11 shows the Activity Awareness Model.

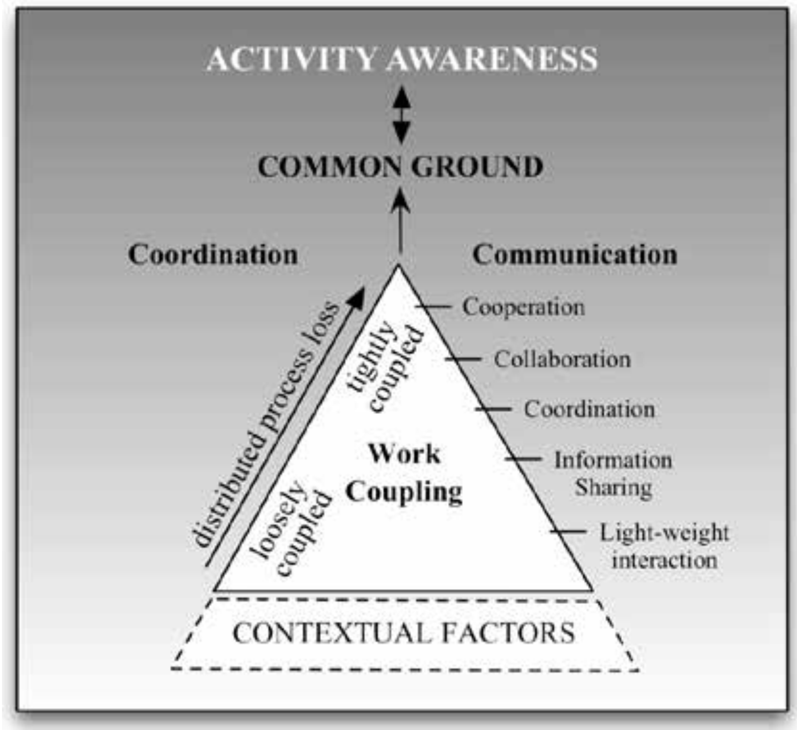


Figure 11: Neale, Carroll, & Rosson's Activity Awareness Model

The research of Neale et al. attempts to identify the relationship between important collaboration variables; contextual factors are foundational and work coupling is assessed from loosely to tightly coupled, depending on the distributed nature of the work. The research posits that the more tightly coupled the work, the more cooperative and collaborative it needs to be in order to be effective. The research is intended as a "step in the direction of better approaches for evaluation of collaborative technologies" [13], [119].

The Model of Coordinated Action (MoCA) is another conceptual model developed for framing the context of complex collaborative situations [17]. The research states that a new model is needed beyond the focus on work or technology to include rapidly increasing diversity of socio-technical configurations. As shown in Fig. 12, the MoCA includes a 7-dimensional conceptual model focused on collaboration to investigate how multiple technologies can be mapped to a single collaborative action.

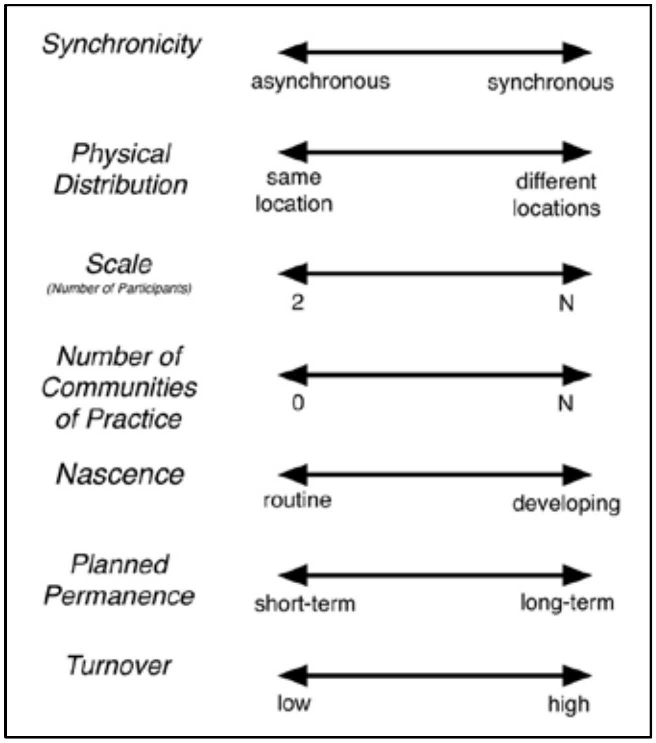


Figure 12: Lee & Paine's Model of Coordinated Action

The MoCA is of particular interest to this research because it ties together the significant contextual dimension that have been covered in CSCW and HCI literature into one integrated contextual model. The MoCA provides a way to tie up many loose threads. More specifically, the researchers posit that the model provides "conceptual parity to dimensions of coordinated action that are particularly salient for mapping profoundly socially dispersed and frequently changing coordinated actions" [17:184]. Lee and Paine suggest that this model provides a "common reference" for defining contextual settings, "similar to GPS coordinates" [17:191].

The HCI and user-centered design involves the careful interpretation of human activities that get translated to unmet needs and wants [123]. User experience design and HCI pioneer Donald

A. Norman states, “We must design for the way people behave, not for how we would wish them to behave” [14:86]. Rooted in cognitive sciences, user-centered design aims to interpret the work that needs to get done and the human interaction associated with that work to guide a human-computer interaction that is intuitive, natural, and easy to use. Arias et al. posit a shift from system design to the intended use or intended work, versus the computing system. The research found that collaborative design facilitates a shared understanding through a more engaged interaction [18]. Aligned with the objects of user-centered design are a variety of HCI tools and methods that are used to facilitate a better interpretation and implementation of the user experience.

HCI experts use a variety of immersive techniques and tools to extract valuable insights from users about the collaborative systems that they otherwise may not be able to articulate, largely centered around usability. Jakob Neilsen, a pioneer in usability engineering, states that system usability determines “whether the functionality of the system in principle can do what is needed” [124:25]. Usability includes both functional aspects of the system and evaluates the intent of the system: Does the system accomplish what it was intended to do? And to what the degree of ease and efficiency? [124]. Rozanski and Haake posit that HCI professionals are charged with understanding computing technology, user behavior and tasks, and the environment (i.e., context) of the system [8].

Usability is defined by international standard ISO 9241-11 as "… the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [125].

Human-centered design is characterized by international standard ISO 13407 as “…the active involvement of users and a clear understanding of user and task requirements; an appropriate allocation of function between users and technology; the iteration of design solutions; multi-disciplinary design" [126], [127], [128].

Contextual inquiry is a popular HCI usability method that incorporates four principals (i.e., context, partnership, interpretation, and focus) into immersive user engagements in order to “go where the user is and observe what they do, collect data on the real activity before starting the project; the team defines the problem to be solved, the users who are affected, the users’ activities and tasks that matter, and the situations and locations that are relevant” [129:41].

Conducting a contextual inquiry is similar to conducting an ethnographic study, yet it has a specific focus on the work task activities and user interaction involved in completing a task [130], [131]. Techniques used by HCI researchers are shadowing, work sampling, task walk-through, think-aloud, and master-expert – all work- and tasked-focused [132]. HCI experts are actively immersed in the field, collecting valuable user information to help guide system development [133]. Tolmie et al. posit that capturing the fine and sometimes mundane details of everyday routines is critical to developing effective systems that efficiently meet user needs [133]. Having both a formative (before the design – current-state) and summative (after the design – future-state) view is necessary for achieving a comprehensive understanding of the workflow [127], [128], [129]. This research is focused on a comparative model and methodology that evaluates formative and summative views of the technology-mediated workflow.

Crabtree states that usability experts looking to “inform the development of collaborative computing systems” are best served by “description, analysis and representation” of the workflow [65:2]. Immersive discovery is a hallmark of HCI systems design that addresses the collaborative needs of users and is a foundation element of this research [134]. Future work should focus on the "research method, data collection, data analysis, and domain of study …. [and] increase realism by making the participants actually complete the assigned work" [19:57], [135].

Gutwin and Greenberg introduce a conceptual framework to evaluate groupware that includes "seven major activities that comprise the mechanics of collaboration" that can be compared with "three criteria measures": effectiveness, efficiency, and satisfaction [136:3]. Fig. 13 illustrates the collaboration framework.

	Effectiveness	Efficiency	Satisfaction
Explicit communication			
Consequential communication			
Coordination of action			
Planning			
Monitoring			
Assistance			
Protection			

Figure 13: Gutwin & Greenberg's Collaboration Framework

This collaboration framework was designed by Gutwin and Greenberg as "middle ground between brittle experimental techniques and time-consuming field techniques." This approach has valid evaluation schema that were introduced to complement usability evaluations and rigorous, sometimes one-off, field work. Yet the approach was not completely developed for generalizable use, and the framework does not measure the existing (formative) workflow for comparison purposes to the technology-mediated (summative) workflow from both qualitative and quantitative perspectives. These gaps present research opportunities for this researcher to address [135], [136], [137].

A more comprehensive HCI user evaluation tool that complements the EU and PU determinants of the TAM is the USE Questionnaire developed by Lund. [26], [138]. The USE questionnaire presents users with a series of statements designed to compare Perceived Usefulness, Satisfaction, Ease of Use, and Ease of Learning. Each positive USE statement is evaluated by the user and rated on a 7-point Likert scale (from strongly agree to strongly disagree.) These USE statements are used to gauge the user's confidence in the system [26], [138].

The results of the USE analysis are represented in a four-quadrant radar chart (as shown in Fig. 14) The percentage of positive reactions is based on the highest percentage of positive feedback from the user experience.

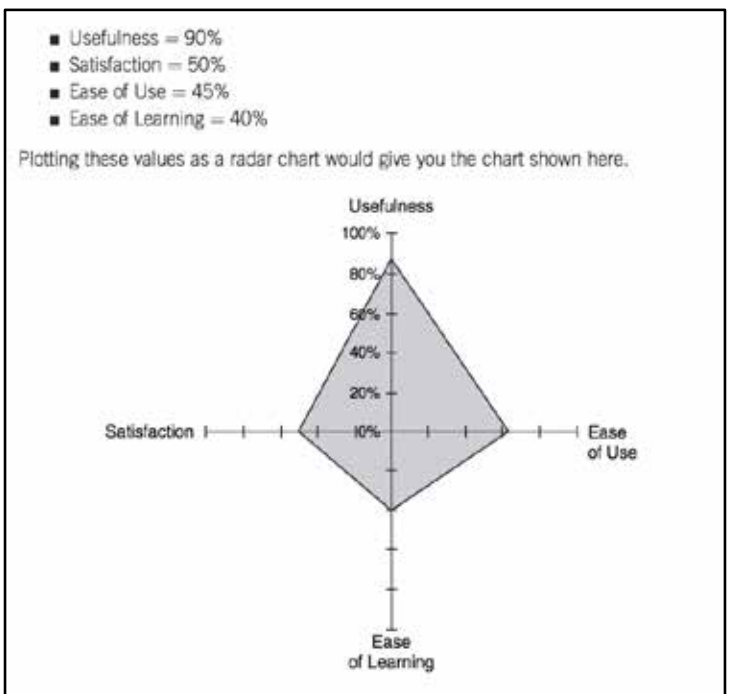


Figure 14: Lund's USE Scale

Brooke's System Usability Scale (SUS) presents users' positive questions about the system that are labeled with odd numbers in the list and negative questions that are labeled with even numbers. A 5-point Likert scale of agreement is used for each [139], [140] [141], [142], [143]. A technique for combining the ten ratings into an overall score (on a scale of 0 to 100) is also given. No attempt is made to assess different attributes of the system (e.g., Usability, Usefulness, etc.). To calculate a SUS score, we will first sum the score contributions from each item (ranging from 0 to 4), and then multiply the sum of the scores by 2.5 to obtain the overall SUS score. For items 1, 3, 5, 7, and 9 (i.e., positive), the score contribution is the scale position, minus 1. For items 2, 4, 6, 8, and 10 (i.e., negative), the contribution is 5, minus the scale position.

Reicheld developed another HCI evaluation tool that again complements the Attitude determinant of the TAM, the Net Promoter Score ™ (NPS) [144], [145], [146]. The NPS is a trademarked metric which measures how likely users are to promote the product to others in their circle of influence. The goal of NPS is to measure the overall perception of a brand and is meant to be complementary to other metrics and insights from other touch points with users such as USE and TAM. Respondents are asked to rate their likelihood of promoting the product on a scale of 0-10 (not at all likely to extremely likely). People scoring from 9 to 10 are considered to be "Promoters," users who will "keep buying and refer others." Those scoring from 7 to 8 are considered "Passives" who are vulnerable to competitors. Those scoring 0 to 6 are considered "Detractors" who are unhappy customers that can damage a brand through word-of-mouth. The percentage of promoters minus the percentage of detractors will return a Net Promoter Score.

The HCI-CSCW arena provides a rich and robust history of research, and practical tools and methods for evaluating the design and usability of computing systems. The methods and tools in use by HCI and CSCW researchers and professionals focus mainly on system usability and do not take a holistic view of the collaborative gaps and gains of the current way a work task is completed by use of technological enhancement. This research looks to address this formative and summative evaluation requirement with a generalizable method that complements many of the prominent CSCW and HCI tools and methods.

2.6 Summary

Related works from four diverse disciplines discussed in this chapter incorporate research findings in immersive discovery, collaboration, technology adoption, and workflow integration techniques, including a unique and robust set metrics that were used to formulate the Collaborative Space – Analysis Framework (CS-AF). In order to conduct immersive discovery and field engagement, the CS-AF integrates well-established ethnographic discovery techniques from the social sciences with similar approaches in CSCW/HCI (such as contextual inquiry) and from the Industrial Engineering Value Stream Mapping approach for a synergistic technique. CSCW/HCI provides extensive research in the area of "context" that build from the Social Sciences to include insights that are relevant to ubiquitous collaboration. The Social Sciences, Organizational Management, and CSCW/HCI disciplines contributed insights and valuable techniques associated with attitude, behavior, and goal setting associated with collaboration and technology adoption.

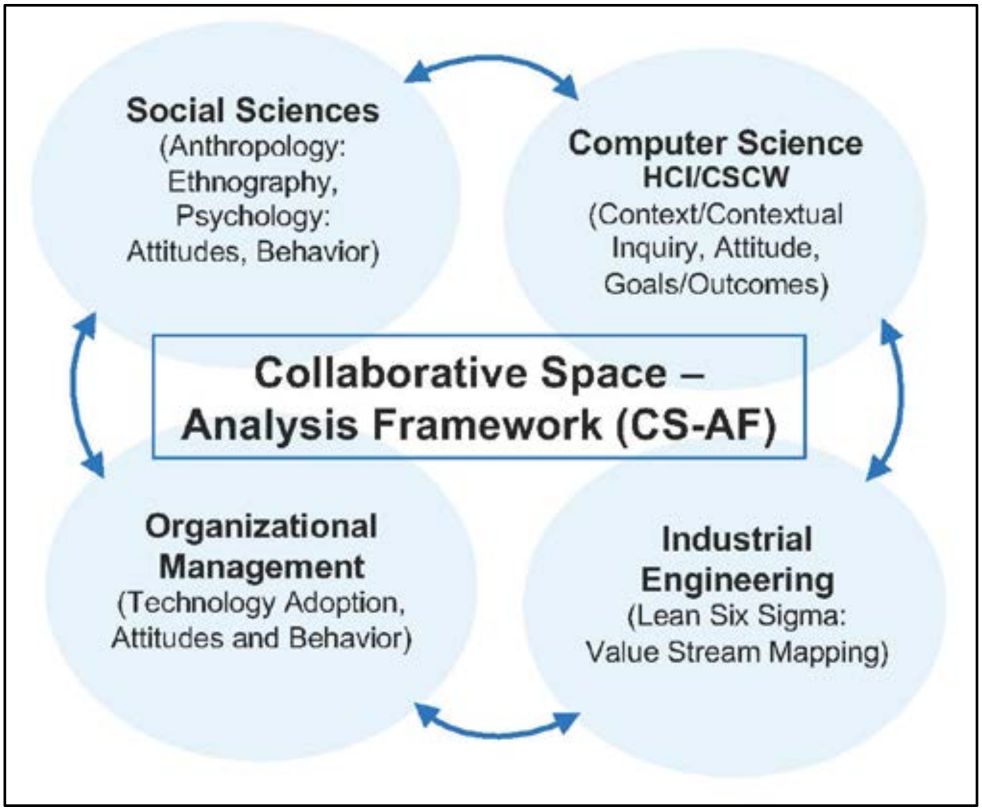


Figure 15: Cross-Disciplinary Related Works, Bondy 2020

Each one of these four discipline contribute valuable components to the formulation of the CS-AF and the concentration of the collaborative workflow evaluation from five key perspectives: Context, Technology, Process, Attitudes, and Outcomes.

Chapter 3

Collaborative Space – Analysis Framework (CS-AF)

3.1 Introduction

Research of collaborative workflows is a topic of high interest from a variety of research disciplines and perspectives, as reviewed in the Related Works section. Evaluation of technology-mediated workflow enhancements incorporates the analysis of enabling technologies, including the physical computing infrastructure, the interaction between human and computer (CSCW/HCI-UX), and informatics (the collection and representation of data within the workflow). This research introduces a model and methodology that is designed to observe and capture field information in a consistent manner, such that essential cross-disciplinary elements of the collaborative workflows can be evaluated and compared.

The Collaborative Space – Analysis Framework (CS-AF) methodology introduced in this research is intended to be utilized onsite where work gets done. The CS-AF is designed to equip researchers with a generalizable approach to explore and evaluate technology-mediated collaborative workflows using cross-disciplinary elements in an integrated fashion. The focus of the CS-AF is the evaluation of both the unique workflow steps and overall workflow required to complete a specific task. With this novel approach to studying collaborative workflow, consistent information can be captured, regardless of the specific discipline of the researcher or the target domain of study, making the CS-AF adaptable to most any task-focused collaborative workflow.

Incorporating a cross-disciplinary approach into a functional model and methodology presents both opportunities and obstacles. Massey et al. studied cross-disciplinary approaches to research and underscored the need for researchers to be immersed in the work site; this immersive engagement brings the researcher to an important vantage point to observe. “To study interdisciplinary collaboration in the doing is to direct attention to the moments where the tensions and contradictions inevitable in interdisciplinary work become unavoidable” [147:145]. Conducting research from a cross-disciplinary view enables a more comprehensive view, yet the researchers also acknowledge that the approach can introduce added complexity when researchers attempt to reconcile contrasting approaches. The CS-AF aims to reduce or eliminate cross-disciplinary complexity by integrating complementary cross-disciplinary elements into a structured methodology that can be implemented by a single researcher.

This research incorporates elements from four different disciplines into an integrated model and standardized methodology in efforts to capture a more comprehensive view to evaluate and compare collaborative workflows. Domain knowledge from the targeted workflow under investigation is also required and incorporated into the CS-AF methodology. For each workflow investigation, specific workflow steps are defined and used to shape a standardized semi-structured survey that incorporates elements from the Social Sciences, Organizational Management, CSCW/HCI, and Industrial Engineering. Fig. 16 illustrates the interdisciplinary components of the CS-AF.

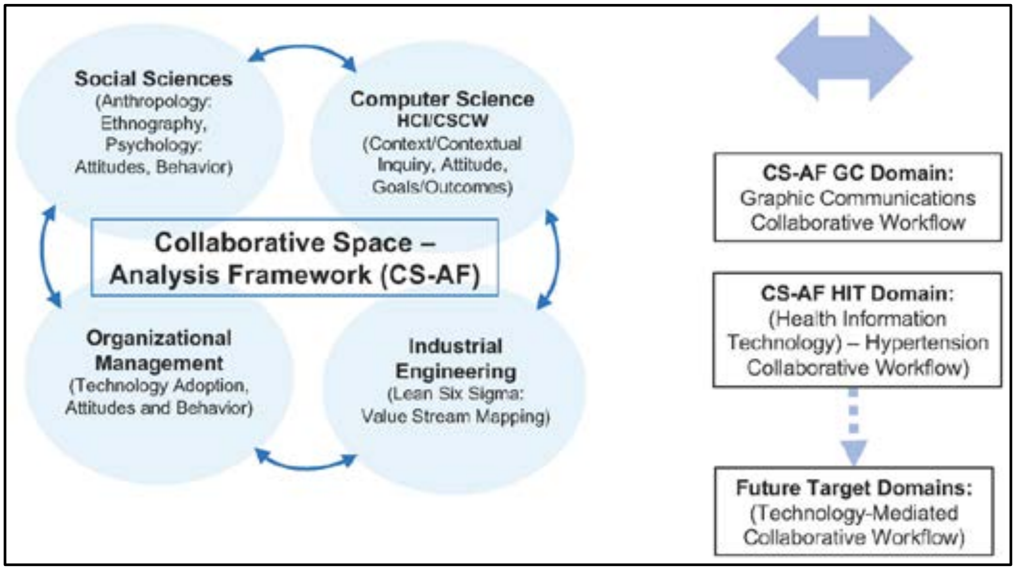


Figure 16: Cross-Disciplinary Components of the CS-AF

The CS-AF introduces a standardized approach to workflow-directed discovery and evaluation, based on consistent cross-disciplinary attributes that enable meaningful comparison between the pre- and post- technology-mediated enhancements in a targeted workflow. This research also implements an empirical field case study utilizing the complete CS-AF methodology in two diverse domains in order to test the approach and validate the generalizability of the CS-AF. The specific cross-disciplinary areas of contribution and emphasis incorporated in the CS-AF are summarized below.

A generalizable model and methodology are needed to provide a consistent approach to evaluate and determine the association between a current-state workflow and a technology-mediated collaborative workflow. Both the HIT and Graphic Communications (GC) domains analyzed in this research are bombarded with new technologies, posing a difficult integration scenario. Both the HIT and GC space have mixed results when it comes to technology adoption and workflow integration; there is no prevailing “best practice” to evaluate the association between the current-state and technology-mediated collaborative workflow. The ideal model should incorporate aspects from a variety of disciples and ensure that a comprehensive qualitative and quantitative evaluation can be accomplished.

3.2 Collaborative Space – Analysis Framework

The CS-AF comprises a variety of cross-disciplinary components that have been purposefully selected to enhance the view that any one single approach has on its own and to integrate the complementary attributes that each of these best-in-class models generates. The aim for the CS-AF is a generalizable, well-integrated, and cross-disciplinary framework that enables a functional approach to collect and evaluate the essential data of collaborative task-oriented workflows. The CS-AF consists of five areas of investigation: Context, Process, Technology, Attitude and Behavioral Intent, and Outcomes.

Core to the CS-AF model is an ethnographic analysis and semi-structured survey methodology designed to measure users' context, workflow processes, technology adoption, attitude and behavioral intent, and outcomes toward the workflow, then compare them with the technology-mediated workflow enhancements. The CS-AF incorporates ethnographic discovery focused on a specific work-practice task (e.g., GC: Sales Quotation workflow, HIT: Hypertension workflow) for field observation. This approach directs the ethnographic analysis in logical predefined steps associated with completing the task or workflow.

Ethnographic field work captures valuable user experience data that can be instrumental in evaluating technology adoption and directing technology development. The CS-AF model integrates cross-disciplinary analysis components together, and the CS-AF methodology delivers a field implementation guide, such that the CS-AF can be implemented by other researchers as a generalizable approach to investigate technology-mediated collaborative workflows.

3.2.1 Components of the CS-AF

TAM as a foundational component used in the formulation of the CS-AF and incorporates other models from other disciplines in efforts to improve the robustness with enhancements necessary to observe and evaluate technology-mediated collaborative workflows. The TAM is a suitable starting place since it is the most popular technology-adoption model used to evaluate individuals. Yousafzai et al. conducted a meta-analysis of TAM and state that the widescale use of TAM is associated with three key factors:

> … (1) it is parsimonious, IT-specific, and is designed to provide an adequate explanation and prediction of a diverse user population's acceptance of a wide range of systems and technologies within varying organizational and cultural contexts and expertise levels; (2) it has a strong theoretical base and a well-researched and validated inventory of psychometric measurement scales, making its use operationally appealing; and (3) it has accumulated strong empirical support for its overall explanatory power and has emerged as a pre-eminent model of users acceptance of technology [25: 264].

Five areas of investigation are incorporated in the CS-AF (Context, Process, Technology, Attitude and Behavioral Intent, and Outcomes; they target a holistic view of a task-oriented collaborative workflow with the aim of an improved cross-disciplinary evaluation that is generalizable to different domains.

CS-AF Context

Identifying the context of the workflow refers to the collaborative user groups that work together, and to the specific settings and modality in which they work. Characterization of the workflow context provides a view into the intended scope or functional containment of the workflow, enabling a more precise focus on the intended environment and conditions of the workflow.

Lee and Paine's Model of Coordinated Action (MoCA) [17] provides a functional approach to describing the context of a collaborative workflow from seven key attributes included in the CS-AF. The CS-AF integrates the MoCA on the front end of the TAM in place of the "external variables"; this yields a more precise approach to capture the context of the workflow than does the external variable approach. The use of external variables in Davis's original model (shown again here in Fig. 17) has been criticized as being too vague a construct, which does not provide designers with information necessary to clearly understand the setting and context of users [24], [25]. Integrating the MoCA with the TAM adds precision to the specific descriptive context of the target workflow in a manner that can be consistently evaluated and easily compared.

The Model of Coordinated Action (MoCA) was developed for framing the context of complex collaborative situations [17]. The MoCA context evaluation method can be easily adapted for workflow context, and it includes seven key contextual elements to better characterize the setting of use, as shown in Fig. 18. The researchers posit that their framework can be adapted and included in other frameworks to offer a more standardized approach to capturing the context of a collaborative workflow for subsequent comparison. "The seven dimensions of MoCA (i.e., synchronicity, distribution, scale, number of communities of practice, nascence, planned permanence, and turnover) provide researchers, developers, and designers with a vocabulary and range of concepts that can be used to tease apart the aspects of a coordinated action that make them easy or hard to design for" [17:191]. Using the MoCA as a standard component of the CS-AF fortifies the overall framework with a practical and structured approach to capturing the workflow context.

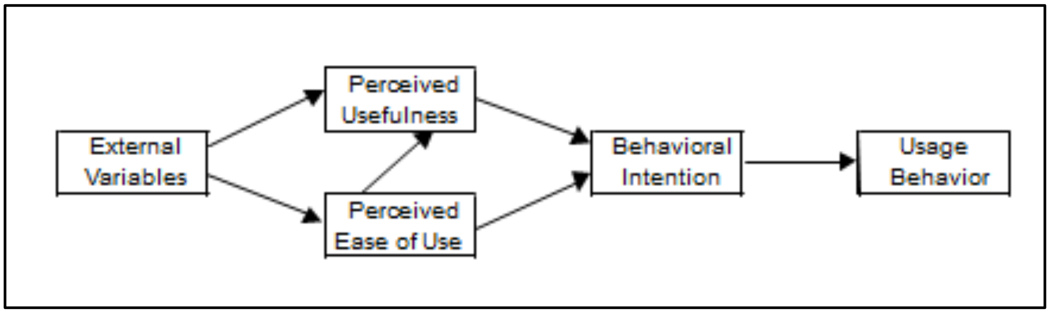


Figure 17: Davis's original TAM model

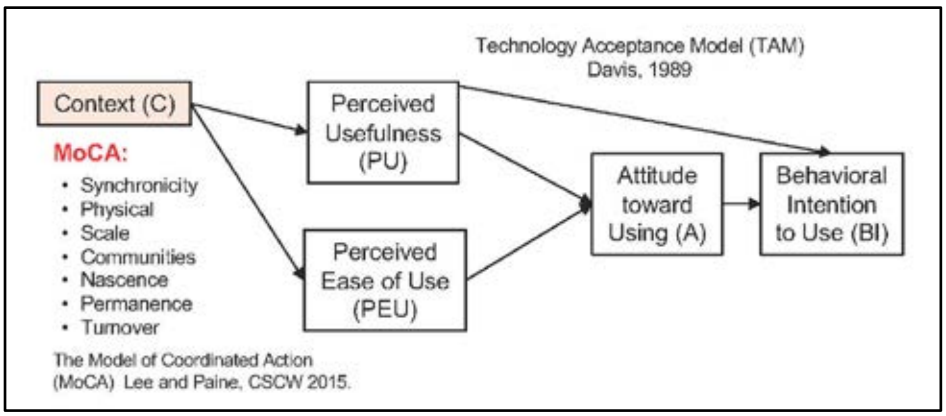


Figure 18: Context component of the CS-AF – MoCA integrated with TAM

Table 3 outlines MoCA context evaluation attributes which are included in the CS-AF and field engagement methodology as a consistent and structured means to evaluate the setting of users in the workflow, along with qualitative questions.

Context		
Context	Comparison based on 7 vectors, provides insights into the complexity, volatility, etc. of the collaborative workflow (MoCA) Lee and Paine, CSCW 2015).	
	Determinant	**Measure**
	Synchronicity	7-point Likert Scale (1-async/4-both/7-sync)
	Physical	7-point Likert Scale (1-same/4-mixed/7-different)
	Scale	7-point Likert Scale (1-6 participants or more-7)

Context		
Context	Comparison based on 7 vectors, provides insights into the complexity, volatility, etc. of the collaborative workflow (MoCA) Lee and Paine, CSCW 2015).	
	Determinant	**Measure**
	Communities	7-point Likert Scale (1-6 communities or more-7)
	Nascence	7-point Likert Scale (1-routine/4-developing/7-new)
	Turnover	7-point Likert Scale (1-low/4-med/7-high)
Qualitative Questions	Does this workflow require you to be physically present? Do you considered this workflow to be a new experience or a familiar experience?	

Table 3: CS-AF Workflow Context Evaluation

CS-AF Process

In addition to social sciences ethnographic influences and HCI/CSCW influences, such as contextual inquiry and task analysis, the IE workflow analysis method of VSM has been incorporated into the CS-AF. VSM incorporates a hierarchical task analysis technique to uncover a quantitative view of the workflow from a cycle-time perspective (by task) and a measure of the information quality at each juncture of the workflow. VSM provides an ethnographic structure that aims the field engagement directly down the path of completing the steps in a targeted workflow, similar to HCI techniques, yet with more quantitative rigor regarding time and quality measures.

VSM in and of itself is does not provide a complete view of the workflow and is, therefore, complemented in the CS-AF by other evaluation elements from HCI/CSCW, such as awareness and goal setting, in order to expand the full participants', view of the collaborative workflow. The CS-AF also incorporates the social science's reflexivity concept into the methodology by targeting a thorough VSM evaluation of current-state and future-state workflow, followed by an analysis and comparison. For each empirical study conducted for this research, logical workflow steps were defined. The research engaged users with semi-structured observation, and structured and unstructured questions associated with each step in the workflow and the overall workflow experience.

The process element of the workflow refers to the specific sequential steps that are involved in the workflow. Each workflow has a number of discrete steps or segments that make up the unique set of processes required to complete a specific work function. All workflows to be evaluated are divided into a series of sequential steps; this exercise provides better precision for the analysis of idiosyncrasies in the workflow.

An IE technique for measuring workflow time and information quality, VSM [28], [49], [50] is applied in the process stage. Each workflow step or key element of the process is first measured for time consideration, which includes cycle time (i.e., duration of task from start to completion), lag time (i.e., time that the workflow is held up waiting), and total time (i.e., entire time required for a workflow step). Quantitative data for the current-state and future-state technology-mediated collaborative workflow are recorded though the survey process.

In addition to evaluating process time, each workflow step is also evaluated from an information quality perspective in order to determine the accuracy and accessibility of information entry and retrieval as they pertain to users at each workflow step.

CS-AF methodology incorporates a semi-structured survey (qualitative and quantitative) that is collected for both the current-state and technology-mediated workflow. The survey data is then evaluated and analyzed to determine the potential collaborative gains and gaps of the targeted workflow.

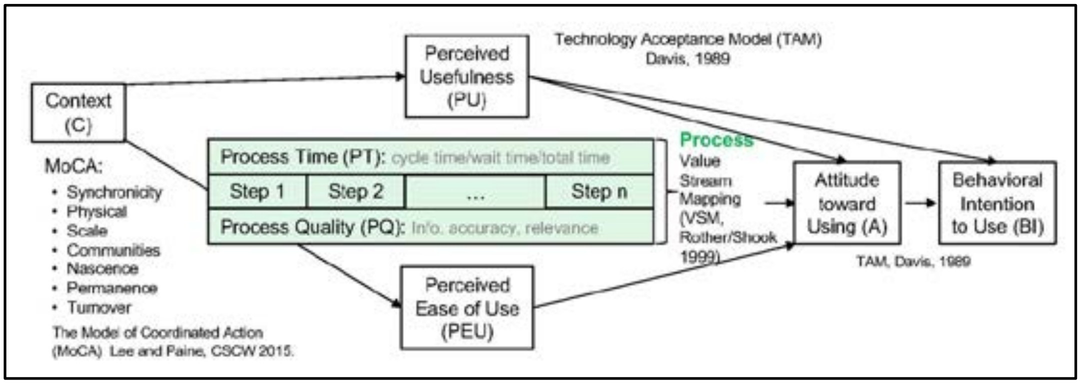


Figure 19: Process component of CS-AF – VSM incorporated with TAM and MoCA

Applying the VSM method to collaborative workflow analysis involves a carefully constructed workflow process that segments the logical steps of the workflow into the discrete sub-processes that can be identified and evaluated on their own, while also evaluated overall as a complete workflow process (as shown in Fig. 19). Each empirical study requires immersive engagement in the workflow prior to constructing the workflow process to ensure the workflow steps are both logical and at a granularity level that will elicit valuable insight, yet are not too finite so as to be cumbersome or to overemphasize a particular workflow step. With my extensive experience evaluating workflow, over time, I have developed a finesse for definition of specific workflow steps at a level that illuminates the activity without overemphasizing the details. Care must be given to the process of comprehending the overall targeted workflow, and then carefully parsing that work into logical steps that will be used to conduct the pre- and post-workflow analyses. If the process steps are appropriately defined, the data collected throughout the CS-AF methodology will yield meaningful results. Table 4 outlines the steps in the process evaluation.

Process		
Process Time	Value Stream Mapping (cycle-time & lag-time at each WF step). Time is calculating in terms of fully-burdened cost to arrive at the time-value per minute, this will provide a dollar value-metric for financial value-gained through workflow efficiencies.	
	Determinant	**Measure**
	Task Time	Time in seconds
	Lag Time	Time in seconds
	Total Time	Time in seconds >> $dollar value of time
	WF Cycle-Time Acceptability	7-point Likert Scale (1-very unacceptable – 7 very acceptable)
Process Quality	Qualitative evaluation of the importance and relevance of the information available at each step of the workflow.	
	Determinant	**Measure**
	Information relevance for each task	7-point Likert Scale (1-very irrelevant – 7-very relevant)
	Information importance for each task	7-point Likert Scale (1-very unimportant – 7-very important)
Qualitative Questions	Is there a particular step in the WF that seemed like a waste of time, elaborate? Is there a particular step in the WF that seemed confusing (poor instructions, not intuitive)?	

Table 4: CS-AF Workflow Process Evaluation

CS-AF Technology

At the core of the CS-AF is the TAM and the focus of technology adoption of the collaborative participants in the workflow. The TAM introduces two crucial constructs aimed to uncover user perspectives related to the adoption of technology. Does the technology enhance the workflow and deliver a more useful and easier to use solution? Davis et al. believed that the two determinants, Perceived Usefulness (PU – enhancement of performance) and Perceived Ease of Use (PEU – freedom from effort), are the essential elements of technology acceptance, and when coupled with a view of the user's attitude toward using the technology, provide a parsimonious and functional model that can deliver a meaningful evaluation of technology adoption [22]. The survey approach used in empirical studies for the original TAM can be complemented with the USE questionnaire developed by Lund [26]. When TAM survey questions surrounding PU and PEU are complemented with two other determinants (Satisfaction and Ease-of-Learning), a more comprehensive evaluation of the collaborative experience can be collected, analyzed, and compared (as shown in Fig. 20). The CS-AF has integrated the TAM approach with the USE questionnaire to collect a multifaceted view of PU, PEU, Satisfaction, and Ease-of-Learning. The portrayal of this information is represented in a 4-facet radar chart that provides the researcher with a visual representation of each facet simultaneously, so that analysis and comparisons are more self-evident. (Figure 14 shows a 4-facet radar chart.)

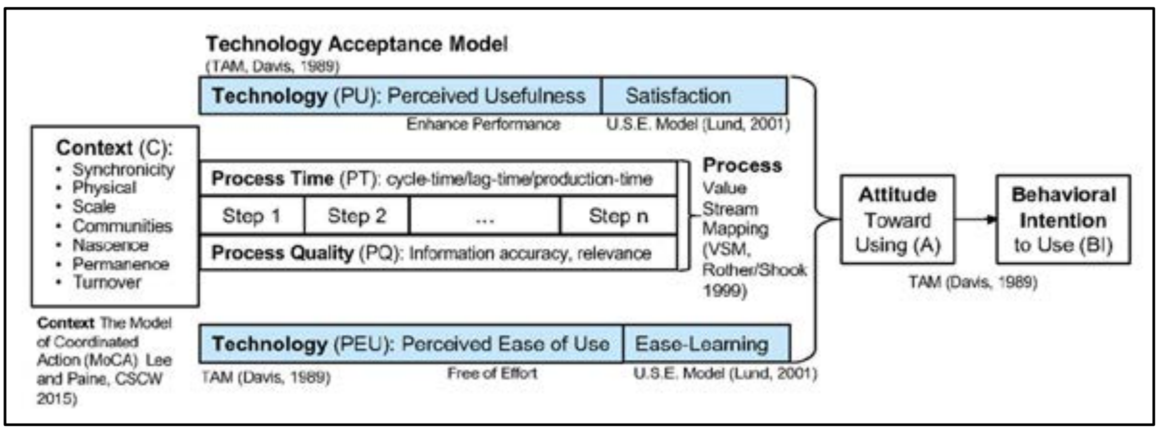


Figure 20: Technology component of CS-AF – USE incorporated with TAM and VSM, MoCA

PU, PEU, Satisfaction, and Ease-of-Learning survey questions are integrated into the CS-AF and methodology, along with qualitative semi-structured questions. The exact same questions are presented to the exact same users, pre- and post- enhancements to the technology-mediated workflow. The final analysis includes comparison between the two data collection efforts, with the only variable being the technology enhancement. This approach isolated the technology enhancement as the unique aspect of the collaborative experience that is being evaluated and compared. (Table 5 outlines the workflow evaluation.)

Technology		
Perceived Usefulness	Qualitative evaluation of how “useful” the technology is in reference to each step in the workflow (TAM, Davis, 1989)	
	Determinant	**Measure**
	How Useful?	7-point Likert Scale (1-very useless – 7-very useful)
	Opportunity to Improve Usefulness?	7-point Likert Scale (1-very unlikely – 7-very likely)
Ease-of-Use		Qualitative evaluation of how “easy-to-use” the technology is in reference to each step in the workflow (TAM, Davis, 1989)
	Easy-to-Use?	7-point Likert Scale (1- very difficult-to-use – 7- very easy-to-use)
	Opportunity to Improve Ease-of-Use?	7-point Likert Scale (1-very unlikely – 7-very likely)
System Usability Scale – USE	The System Usability Scale (USE) questions compare; Perceived Usefulness, Satisfaction, Ease of Use, and Ease of Learning (Lund 2001). “Each is a positive statement (e.g., "I thought the system was easy to use"), user rates level of agreement on a seven-point Likert scale (The results of this analysis are presented using a four-quadrant radar chart).	
	Determinant	**Measure**
	Ease-of-Use	7-point Likert Scale (1-strongly disagree – 7-strongly agree)
	Perceived Usefulness	7-point Likert Scale (1-strongly disagree – 7-strongly agree)
	Satisfaction	7-point Likert Scale (1-strongly disagree – 7-strongly agree)
	Ease-of-Learning	7-point Likert Scale (1-strongly disagree – 7-strongly agree)
Qualitative Questions	Is there a particular step in the WF that seemed difficult to use? elaborate? Do you believe that this workflow is effective for you to accomplish your goal? elaborate?	

Table 5: CS-AF Workflow Technology Evaluation

CS-AF Attitude and Behavior

The original TAM includes evaluation of Attitude Towards Using and Behavioral Intent to Use, which are valid and important determinates included in the CS-AF and are applicable to the evaluation and analysis of collaborative workflow. In order to collect an expanded assessment of the user’s perspective towards the workflow, the baseline TAM attitude and behavior constructs are complemented in the CS-AF by additional semi-structured qualitative questions.

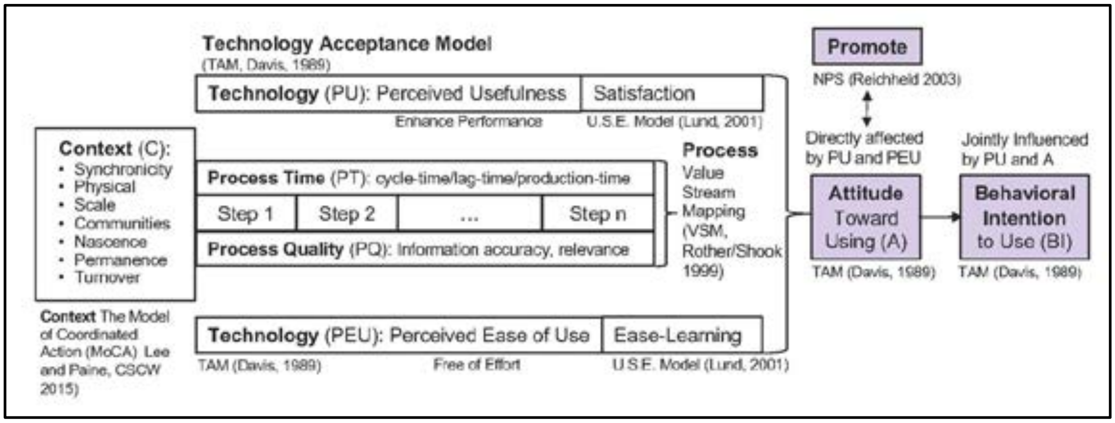


Figure 21: Attitude & Behavior component of CS-AF – NPS integrated with TAM, USE, VSM, and MoCA

As shown in Fig. 21, the CS-AF also incorporates the Net Promoter Score™ (NPS) [27] in attempts to further understand the Attitude determinant of the TAM [22]. The NPS is a trademarked metric which measures how likely users are to promote the product to others in their circle of influence. The goal of NPS is to measure the overall perception of a brand, or in the case of the CS-AF, the workflow as a complementary metric to the TAM. Respondents are asked to rate their likelihood of promoting the product on a scale of 0-10 (not at all likely to extremely likely). People scoring from 9 to 10 are considered to be Promoters, users who will "keep buying or using and refer the workflow to others" [22]. Those scoring from 7 to 8 are considered Passives who are vulnerable to competitors or other alternative workflows. Those scoring 0 to 6 are considered Detractors who are unhappy customers that can damage a brand or perception of the workflow through word-of-mouth. The percentage of Promoters minus the percentage of Detractors will return an NPS.

Attitude and Behavior		
Attitude	Quantitative comparison of users' attitude toward using the technology incorporated in the workflow (TAM, Davis, 1989).	
	Determinant	**Measure**
	Positive Opinion about the WF?	7-point Likert Scale (1-strongly disagree – 7-strongly agree)
	Using the WF is good for me?	7-point Likert Scale (1-strongly disagree – 7-strongly agree)
	The WF is appropriate form me?	7-point Likert Scale (1-strongly disagree – 7-strongly agree)

Attitude and Behavior		
Behavioral Intent	Quantitative comparison of users' behavioral intent toward using the technology incorporated in the workflow (TAM, Davis, 1989).	
	Determinant	**Measure**
	I intend to use the WF?	7-point Likert Scale (1-strongly disagree – 7-strongly agree)
	I expect my use of the WF will continue?	7-point Likert Scale (1-strongly disagree – 7-strongly agree)
Net Promoter Score (NPS)	Quantitative comparison of users' likelihood of promoting (recommending) the product/workflow to a friend or colleague (Reichheld, 2003).	
	Determinant	**Measure**
	How likely is it that you would recommend this WF to a friend?	Scale of 0 to 10 (0 being "Not at all likely" and 10 being "extremely likely).
Qualitative Questions	Do you feel satisfied with how you accomplished your task? elaborate? Did any part of this workflow frustrate you? elaborate?	

Table 6: CS-AF Workflow Attitude and Behavior Evaluation

CS-AF Outcomes

The focus of the CS-AF and methodology is the evaluation and analysis of collaborative workflows that are targeted at a work task. With "work-task" focus in mind, it is crucial that the CS-AF incorporates an evaluation and analysis of the user's view of the goals and objectives associated with the workflow. Critics of the TAM believe that putting too much weight on external variables and behavior intentions, and not giving enough consideration towards user goals in the acceptance and adoption of technology, is a limitation of the TAM in all its forms [90]. The CS-AF incorporates a provision to acknowledge user goals leveraging CSCW/HCI concepts in awareness and goals setting established in the Activity Awareness Model [13], [119].

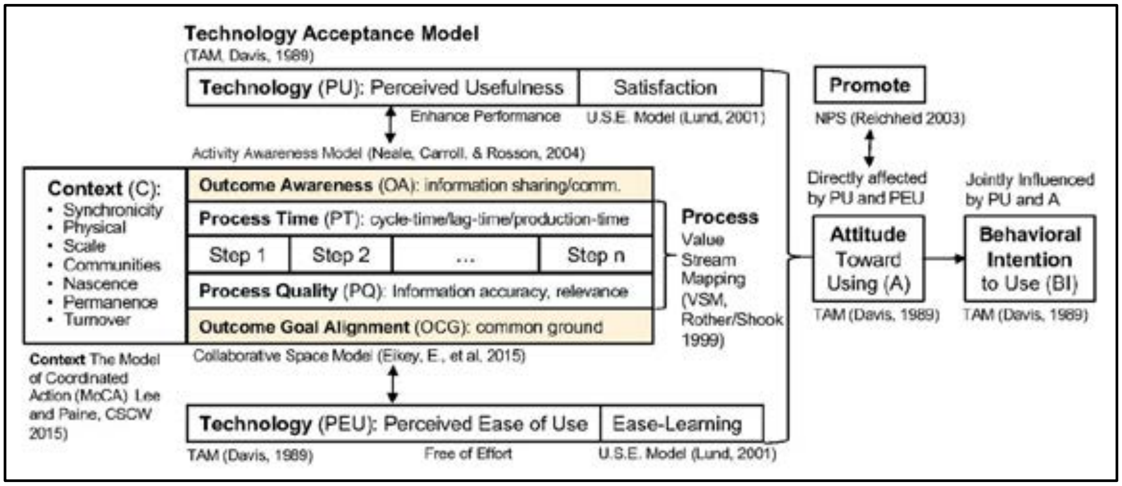


Figure 22: Outcomes component of the CS-AF – AAM integrated with TAM, NPS, USE, VSM, and MoCA

The Activity Awareness Model highlights the need for researchers to capture and evaluate user goals. As shown in Fig. 22, the CS-AF incorporates two determinants, Awareness and Goal Alignment, that are collected by users along each process step in the workflow in attempts to pinpoint target outcomes for collaborative users of the workflow [13], [119].

Awareness refers to how individual users of the workflow feel that others involved in the workflow are aware of their communications needs. Do they provide the information that is needed? Do they know when there is an information request? Goal alignment refers to how individual users of the workflow feel others involved in the workflow share mutual common ground with respect to desired outcomes of the workflow. The data points of outcomes are captured using a qualitative research survey for both the current-state and technology-mediated collaborative workflow. Table 7 outlines the process for a workflow outcomes evaluation.

Outcomes		
Awareness	Quantitative comparison of users' perception regarding awareness of participants in the workflow related to information sharing and communications (Neale, Carroll & Rosson, 2004).	
	Determinant	**Measure**
	How aware are others (Dr.) of your goals for each step in the WF?	7-point Likert Scale (1- very unaware – 7-very aware)

Outcomes		
	How complete was the communications at each step in the WF?	7-point Likert Scale (1- very complete – 7-very incomplete)
Goal Alignment	Quantitative comparison of users' perception regarding goal alignment with participants in the workflow (Neale, Carroll & Rosson, 2004).	
	Determinant	**Measure**
	How aligned do you feel others (Dr.) are with your goals for each step in the WF?	7-point Likert Scale (1- very unaligned – 7-very aligned)
	How complete was the communications at each step in the WF?	7-point Likert Scale (1- very incomplete – 7-very complete)
Qualitative Questions	What was your primary goal for this workflow? Did you have any sub-goals for this workflow? elaborate?	

Table 7: CS-AF Workflow Outcomes Evaluation

The integrated CS-AF includes carefully selected cross-disciplinary evaluation components that attempt to represent a comprehensive view, while also introducing a structured model and methodology that can be applied consistently in a generalizable manner to task-oriented technology-mediated collaborative workflows. Utilizing the accepted popularity and parsimonious virtues of the TAM, while incorporating essential additions from the social sciences, HCI/CSCW, and IE into the CS-AF enables a robust and versatile model and methodology for empirical collaborative workflow analysis.

The CS-AF introduces a structure to investigate critical dynamics of collaboration in a technology-mediated workflow by incorporating five collaborative components of Context, Process, Technology, Attitudes & Behavior, and Outcomes into an integrated analysis framework (as shown in Fig. 23). Each of these components, when fully integrated in the CS-AF, provide an expanded view of collaboration that can be used to evaluate workflows. Both qualitative and quantitative data are collected from a current-state and technology-mediated collaborative workflow using the CS-AF, and then are compared and analyzed to determine the associated benefits and barriers. The next section introduces the step-by-step procedural methodology to conduct empirical research of collaborative technology-mediated workflow in the field using the CS-AF.

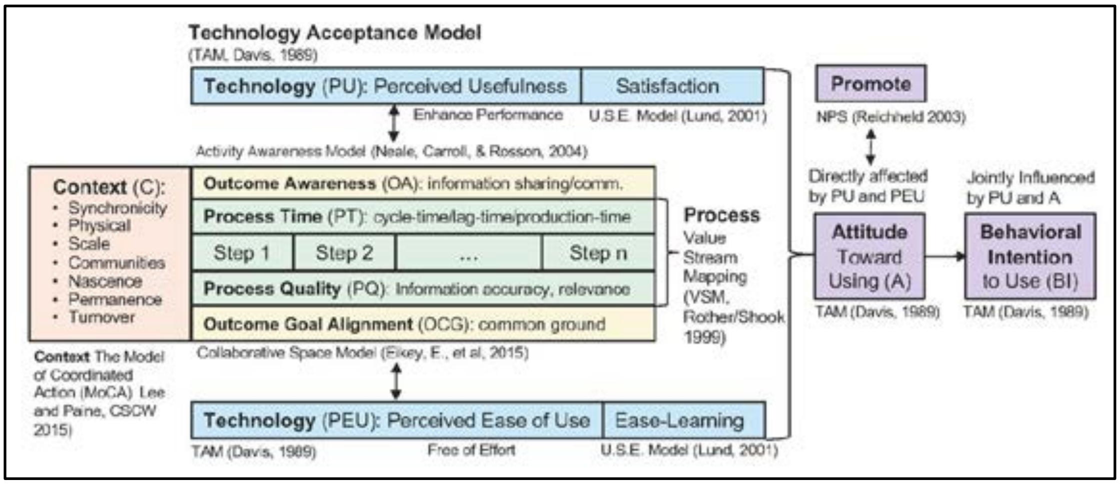


Figure 23: Bondy's Collaborative Space - Analysis Framework CS-AF – V2

3.2.2 CS-AF Deployment Methodology

The Collaborative Space - Analysis Framework (CS-AF) includes both a model and methodology intended to direct the empirical research of technology-mediated collaborative workflows through a semi-structured cross-disciplinary evaluation. In the previous section, the CS-AF model was discussed, highlighting the five components of the CS-AF and how essential cross-disciplinary components are integrated to enable a comprehensive view of the target workflow. Critical to the success of the CS-AF (in terms of repeatability, comparative evaluation, and generalizability) is the CS-AF methodology. Adherence to the specific sequence and steps outlined in the CS-AF methodology is essential to the success of the research. The CS-AF methodology is designed to be utilized with the CS-AF model and survey instrument to ensure consistency so that the data collection will illuminate the transformational characteristics of the technology-mediated workflow, compared to the current-state workflow. Collaborative workflow research is very time-consuming and costly, and it requires a disciplined research protocol to achieve a successful comparative evaluation. Conducting collaborative workflow research using the CS-AF model, but not following the specific sequential steps of the CS-AF methodology will yield unpredictable and less-than-optimal evaluation results.

The CS-AF methodology includes a procedural process for conducting collaborative workflow research using the CS-AF. All information is collected on-site though detailed workflow audits and semi-structured interviews following the CS-AF survey instrument with the participants in the workflow. The research also requires a development and implementation phase whereby the technology-mediated enhancements are integrated into the workflow. Following the transformation of the collaborative workflow, the same participants are re-evaluated using the same CS-AF survey instrument and procedures. When all the data for both the current-state and technology-mediated collaborative workflows are collected, the two workflow scenarios are evaluated and analyzed, and a summary perspective is derived.

The CS-AF methodology [148], [149] includes five sequential steps that are followed in series by completing all the aspects of one step before moving on to the next step in the sequence. As illustrated in Fig. 24 and listed sequentially here, the five steps in CS-AF methodology are:

1. Current-State Workflow Definition - CS-AF Survey Refinement
2. CS-AF User Survey - Current-State Workflow Analysis
3. Technology-Mediated Enhancement – Development Field

Implementation (Usability Test and Technology Deployment)

4. CS-AF User Survey - Technology-Mediated Collaborative Workflow Analysis

5. CS-AF Collaborative Workflow Analysis – Evaluation between Current-State and Technology-Mediated Collaborative Workflow

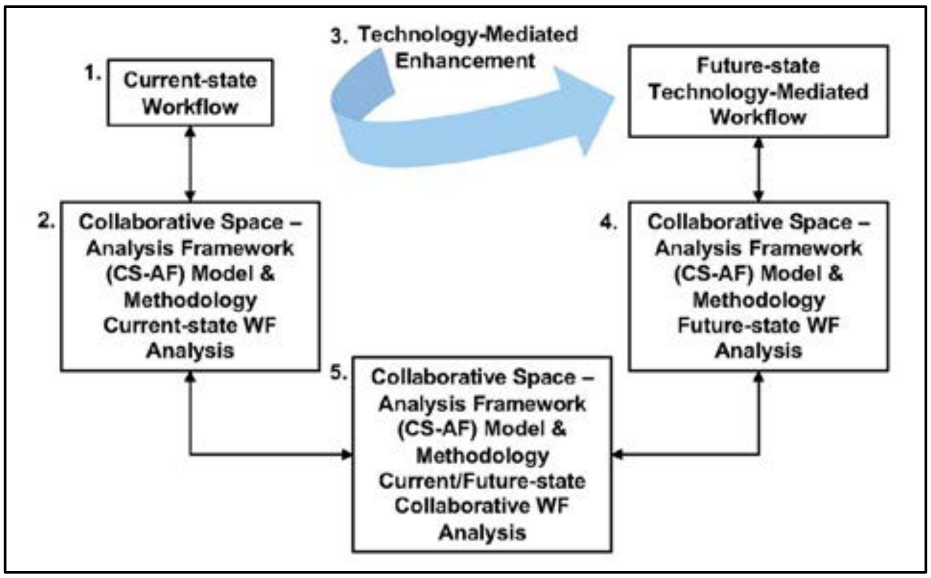


Figure 24: Bondy's CS-AF Deployment Methodology

CS-AF Methodology Sequential Steps

CS-AF Step 1: Current-State Workflow Definition - CS-AF Survey Refinement

The initial step in the CS-AF is to identify and document the specific process steps that are required for the current-state workflow. Each workflow step is considered to be a discrete segment of the workflow that has a user action and output (input, process, and output) and advances the work process forward to the next logical juncture in the sequential process from start to finish. Defining the process steps is an import aspect of the CS-AF, as it provides the structured steps necessary for refinement of the qualitative and quantitative survey and data collection materials for the specific workflow.

It has been my experience that definition of the workflows steps requires an immersive ethnographic effort. The only way to define a workflow is for me to go to the site where the work is getting done, and then to observe both structured and unstructured behavior and activity of the collaborative participants in the workflow. Documenting the specific steps in the workflow can be captured manually through note taking or captured by an unobtrusive video camera such as a Go-Pro device.

It is important to achieve a balanced granularity when defining the workflow step. An overly finite view of the workflow will present too many steps, and can be cumbersome and redundant to evaluate, while a coarse view may omit needed details. My extensive workflow engineering experience has led me to discover that a view of the workflow of 5-15 steps will accommodate most workflows and provide an adequate detail level to address users' perspectives on the collaborative experience. Workflows that require more than 15 steps are typically easier to evaluate in segments by identifying an intermediate work task that is the focus of the targeted enhancement, and then tailoring the evaluation to that specific segment of the workflow. In the case of a partitioned workflow, iterative work is needed in the domain space with workflow participants to ensure that the segmented portion of the workflow under investigation is a realistic view from the users' perspective.

The result of this initial observation effort is a workflow diagram or numbered list that reflects the specific steps that are required in order to complete the target work task under investigation for the collaborative workflow research. These workflow steps that have been defined are then integrated into the CS-AF survey instrument in order to establish the structure that will direct the semi-structured workflow participant interviews. These workflow process steps are evaluated and measured for both the current-state and technology-mediated collaborative workflows.

Refinement of the CS-AF survey is a critical step in the CS-AF methodology, since the survey instrument is tailored for each targeted workflow under investigation. The defined workflow steps are used as a foundational structure to collect all workflow information in Steps 2 and 3 of the CS-AF methodology. This refinement of the CS-AF survey instrument provides a consistent methodology and reference to evaluate and record all important aspects of the current-state and technology-mediated collaborative workflow.

CS-AF Step 2: User Survey - Current-State Workflow Analysis

Establishing a current-state workflow baseline is an essential step of the CS-AF methodology, as this current-state workflow assessment establishes the ground-truth participants' view of the workflow. This includes a determination of the cycle-time and information requirements of each stage and for the participants in the collaborative workflow. The integration of IE workflow evaluation techniques in VSM, coupled with the full complement of cross-disciplinary evaluation metrics integrated into the CS-AF model and survey instrument, directs the semi-structured quantitative and qualitative data collection process.

The discovery begins with determining the current-state workflow context (synchronicity, physical distribution, scale, communities of practice, nascence, planned permanence, and turnover). Establishing the context or setting for the workflow is essential, since this effort provides boundary conditions, manages the scope, and ensures a focused effort in the workflow analysis. The MoCA [17] establishes seven dimensions that can be considered as a range or continuum for the workflow; for example, the synchronicity continuum ranges from activities that occur at the same time (i.e., synchronous) to activities that occur at different times (i.e., asynchronous). Evaluating the current-state workflow from a continuum across these seven different context dimensions establishes the framework for the workflow analysis.

Next, the process metrics for the current-state workflow are evaluated. For each workflow step, process times are recorded: cycle time (start to finish time of each workflow step), lag time (time in between workflow steps), total production time (beginning to end of the entire workflow) using VSM and use case models to collect this information [22] [26]. The information quality requirements for each participant (information provided, information required, and identification of gaps) is also collected for each step in the workflow.

The participant's perspective of the technology used in the current-state workflow based on two specific elements: (1) perceived usefulness, and (2) perceived ease-of-use [22]. Participants are presented CS-AF survey questions in a 7-point Likert scale ranging from very important, slightly important, neutral, slightly unimportant, to very unimportant.

The attitude and behavior of each participant toward the technology used in the current-state workflow is evaluated based on two specific elements: What is your attitude toward using the technology incorporated in the workflow? What is your intention to use the workflow/technology? [22].

Finally, the specific participant goals and a gauge of the awareness of other participants toward those goals are collected for each step of the workflow [13], [119]. Participants are presented survey questions in a 7-point Likert scale ranging from very aware, slightly aware, neutral, slightly unaware, to very unaware for these questions: (1) Awareness Information Sharing and Communications: For each stage in the workflow, how aware do you feel people are of your goals? (2) Goal Alignment: Is there a shared common ground? How likely does the information quality meet your needs at each step in the workflow? How aligned do you feel people are with your goals at each step of the workflow?

Once the CS-AF survey information in this immersive participant engagement for the current-state workflow is completed, all data collected is tabulated in a spreadsheet for analysis purposes.

CS-AF Step 3: Technology-Mediated Enhancement – Development and Field Implementation

Through iterative and agile software development process (define, develop, integrate, and validate), the specific workflow enhancements aimed at optimization or expanded capability to the workflow are implemented. Information collected from the current-state workflow analysis (Step 2) is used to identify specific inconsistencies and inefficiencies that can be addressed (i.e., improved or eliminated) with a technology-mediated workflow. Specific enhancements to the workflow (including streamlining, integration or elimination of steps, improved information quality, and ease of use) are considered at this stage.

Upon completion of a thorough workflow analysis, and prior to beginning development on the technology-mediated workflow, a development plan (including a usability study and prototypes) should be completed and vetted with stakeholders and users.

The technology-mediated workflow can now be developed with specific design and workflow objectives established. To ensure that the optimization goals for the technology-mediated workflow can be achieved with minimal disruption to the operations, adherence to an agile development process (including typical software development processes and controls) is essential in this step.

Once development and a thorough design verification test have been completed, the technology-mediated workflow can be staged alongside the current workflow or be deployed into mainstream operations as each step of the workflow proves to be complete and error-free.

When the technology-mediated collaborative workflow is fully implemented and operational, it is time to advance to Step 4 of the CS-AF.

CS-AF Step 4: User Survey – Technology-Mediated Collaborative Workflow Analysis

Step 4 of the CS-AF methodology repeats the immersive workflow participant survey followed for Step 2, with an update to the specific workflow steps that may have been eliminated with the technology enhancements. The exact same qualitative and quantitative survey information that was collected for the current-state workflow in Step 2 is now collected for the technology-mediated workflow. Step 4 is a crucial step as the information collected in this field participant engagement is used to establish the final collaborative workflow comparison. The same process and rigor established for the CS-AF participant survey of the current-state workflow is conducted now for the technology-mediated workflow / post-technology enhancement. It is imperative that the exact same qualitative and quantitative survey instruments are used with the exact same participants, such that the subsequent analysis is a direct 1:1 comparison, with the only variable being the technology-mediated workflow.

CS-AF Step 5: Collaborative Workflow Analysis – Evaluation between Current-State and Technology-Mediated Workflow

In this step, the current-state and technology-mediated workflow is compared and contrasted using the qualitative and quantitative data collected from CS-AF survey instrument. First, an independent summary of the qualitative and quantitative results for each workflow (current-state and technology-mediated) is completed. Then the data from both current-state and technology-mediated workflows is evaluated and compared, the results are analyzed, and a summary conclusion is formulated. The summary analysis included both a qualitative and quantitative evaluation and comparison of the current-state and technology-mediated workflow in the same structure and detail introduced in the CS-AF. Further summary and analysis are provided with respect to the overall observations of the collaborative gains and losses in the workflow, including identification of areas of optimization, as well as areas where tangible progress in the workflow are negligible [148], [149].

3.3 CS-AF Analysis Methodology

3.2.1 CS-AF Survey Design

The CS-AF survey instrument is an integrated set of 104 qualitative statements that are ranked by test participants' using a 7-point Likert scale for 5 major areas of investigation (Context, Process, Technology, Attitudes & Behaviors, and Outcomes). The survey instrument incorporates single-response statements such as "How easy-to-use is the technology that is incorporated in each step of the 'at home' manual blood pressure exam workflow to you?" Respondents would choose (i.e., self-report) the response that they feel is the best match from an ordered scale: 1-Extremely Easy, 2-Easy, 3-Slightly Easy, 4-Neither Easy nor Difficult, 5-Slightly Difficult, 6-Difficult, 7-Extremely Difficult [150].

The use of Likert-type scales for HCI user-preferences, attitude, and behavior research is quite common, yet researchers have concerns with respect to the ordinal or nominal data aspect of Likert scales, the analysis methodology, and self-reporting nature of this approach. Researchers have debated about the most effective way to analyze the ordinal data from Likert scales, i.e., whether using parametric or non-parametric analysis methodology is most acceptable [151].

Statistical analysis using parametric tests assumes that the population distribution(s) from which the data has been drawn follows certain characteristics, including having a normal distribution and a measurement of a continuous variable (interval or ratio scale), and that the conditions or groups have equal comparisons of mean values. Parametric tests include the 2-sample paired *t*-test, the one-way repeat measures ANOVA used in this study, amongst others; the tests are parametrized by mean and standard deviation. Statisticians prefer the use of parametric tests because there is a variety of tests that can be used to address a broad range of experiments, and because parametric tests are generally better at detecting an experimental effect. Conversely, non-parametric tests (e.g., Wilcoxon Signed Ranks and Mann-Whitney) do not require the underlying data such as preferences data that have a rank without a numerical interpretation in order to follow a normal distribution. Ranked data does not include information about the magnitude of difference between the scores and, therefore, is characterized by statisticians as being less powerful than a parametric test requiring a larger sample size in order to reach the same conclusion with the same degree of confidence that a parametric test offers [152].

Debates exist among statisticians on the validity of ranked data and the appropriate statistical analysis methodology associated with ranked data. Related research posits that the use of ranked data, such as Likert-scales, can be analyzed using parametric test when certain conditions are met.

Harpe posits that there is a common descriptive statistics-to-data relationship:

> …modes [are] for nominal data, medians for ordinal data, arithmetic means for interval data, and geometric or harmonic means for ratio data. This rule stated that nonparametric statistical tests were appropriate for ordinal data, and parametric approaches were reserved exclusively for interval or ratio data. Parametric tests were those that assumed the data followed a normal distribution (e.g., *t*-test or analysis of variance ANOVA), while nonparametric approaches were those tests that did not assume a normal distribution (e.g., Mann–Whitney U-test or Kruskal–Wallis test). This resulted in considerable disagreement within the statistical community [153].

Harpe continues to posit that there are more nuances at the dividing line between the use of parametric and non-parametric descriptive statistics in the case of Likert scales. Harpe states that there are instances when Likert data can be viewed as continuous, namely when the items of the Likert scales are used as a group, not at the item level. He recommends that *"*scales that have been developed to be used as a group must be analyzed as a group, and only as a group*"* [153:840]. The original intention of Likert scales was to provide an aggregated view of a group of items, not a specific item [150]. Harpe states that *"*the unit of inference should match the unit of analysis" [153:840]. In the case of Likert scales, analysis should be at the group level, not at the item level; "… to use only nonparametric approaches for aggregated rating scales is overly restrictive and not reflective of the manner in which these scales were developed" [153:842]. Vicker's research showed that Likert scale data is both interval and linear; therefore, parametric tests, such as repeat measures analysis of variance (*r*ANOVA) or a matched pairs *t*-test, can be used in this situation, as long as the appropriate assumptions hold [154].

When Likert data is aggregated, as a group, there are certain conditions where parametric analysis is appropriate. Harpe states that, "thankfully, empirical studies have shown that some common parametric methods, especially the *t*-test and F-test, are relatively robust to violations of normal distribution and equality of variance provided that two-tailed hypothesis tests are used and the sample sizes within groups are reasonably similar" [153:842].

Several sources present a checklist of conditions where aggregated Likert scale data can be analyzed as parametric [155], [156], [157], paraphrased from 3 online sources]. These conditions are also supported by Harpe's view that, independent of observations (group aggregate), homogeneity of variance and a normal distribution are the required criteria when Likert data can be analyzed with the use of parametric analysis [153:842]. Specifically, parametric descriptive analysis (estimating unknown parameters), using a 2-sample matched pairs *t*-test can be used when the following criteria are met:

- There is a dependent variable that is continuous (i.e., interval or ratio level.) All questions *must* use the same Likert scale and be a defendable approximation to an interval scale (i.e., coding indicates magnitude of difference between items, but there is no absolute zero point.)
- The paired measurements must be recorded in two separate variables.
- There are related samples/groups (i.e., dependent observations.)
- The subjects in each sample, or group, are the same. This means that the subjects in the first group are also in the second group.
- There is a random sample of data from the population.
- There is a normal distribution (approximately) of the difference between the paired values
- No outliers are in the difference between the two related groups.
- When one or more of the assumptions for the Paired Samples *t*-Test are not met, the nonparametric Wilcoxon Signed-Ranks Test may be run instead.

Further validation of this approach is supported by the research of de Winter and Dodou, who conducted a study to determine the capabilities of the 2-sample matched-pairs *t*-test and the Mann-Whitney test to analyze Likert scale items for two groups. The research drew independent pairs of samples to test all possible combinations of a diverse set of 14 distributions representative of actual Likert data. This research included a sum of 10,000 random samples that were generated for 98 distribution combinations. The pairs of samples were then analyzed using both the 2-sample matched-pairs *t*-test and the Mann-Whitney test to compare how well each test performs for different sample sizes. The test results showed that for most pairs of distributions, the difference between the statistical power of the two tests is trivial. Further, for all pairs of distributions, the Type I (i.e., false positive) error rates are very close to the target amounts, concluding that either analysis or results are statistically significant, without concern for false positives. If a difference truly exists at the population level, either analysis is equally likely to detect it. [158].

Meek et al. posit that the standard *t*-test proved more accurate for small sample Likert scale data than did the Wilcoxon signed-rank test, especially when the data follows a normal distribution following analysis of error rates for 27,850 data sets. "Recommendations in the literature for using Wilcoxon's signed-rank procedure over the *t*-test, particularly with small sample sizes and Likert scale data, appear to be groundless, even when the t-test's assumptions are violated" [159].

The 2-sample matched-pairs *t*-test (also referred to as the Dependent *t*-Test, Paired *t*-Test, and Repeated Measures *t*-Test) is a parametric test that compares two means that are from the same individual, object, or related units. The purpose of the test is to determine whether there is statistical evidence that the mean difference between paired observations on a particular outcome is significantly different from zero. The two means can represent measurements taken at two different times, two different conditions, or from half or sides of a subjective experiment. All items measure a single latent variable (i.e., a variable that is not directly observed, but rather inferred from other variables that are observed and directly measured.) The 2-sample matched-pairs *t*-test is analyzed using parametric tests. Similar to the *t*-test, ANOVA (using analysis of variance) is a parametric test used to analyze two or more groups by analyzing the variances to determine if the means are equal or not. For ANOVA analysis, the assumption is that each sample is independent and random, and the population to analyze is, like the *t*-test, from a normal distribution with equal standard deviations [160].

For this research, with validation of a normal distribution, a parametric repeat measures ANOVA (rANOVA) across 5 workflow stages for each group, "analysis that tests whether differences exist among population means with measures on the same subjects" [164:372]. When rANOVA within and between groups analysis generates significant p-values <.05, subsequent 2-sample matched-pairs *t*-test will be used to analyze whether there is statistical evidence that the mean difference between paired observations on a particular outcome is significantly different from zero for specific group-to-group analysis at the determinate or dependent variable level.

The data analysis includes a Group 1 comparison between the baseline and the manual workflow (control group), and a Group 2 comparison between the baseline and the technology-mediated CS-AF survey, and a comparison between the Group 1 difference and Group 2 difference. If the assumption of a normal distribution of the differences is unjustified, then a non-parametric paired two-sample *t*-test, the Wilcoxon matched-pairs signed-ranks test, would be performed. For analysis between the workflow stages of each group and comparison of multiple groups (Group 1, Group 2, and the baseline,) a one-way repeat measures analysis of variance (*r*ANOVA) will be used.

In addition to the Likert scale data, the CS-AF survey includes 15 subjective questions intended to provide further themes from respondents on specific areas in question. The response from subjective questions were collected and evaluated to provide additional commentary and participant perspectives on targeted areas in the survey.

Self-reporting survey questionnaires can present a variety of risks, including under-reporting, respondent bias, and memory lapses. Issues with self-reporting surveys are most prevalent in situations where the respondent is on their own to report directly with the survey instrument (manually or online) and with no context setting and clarification from the researcher. Researchers can minimize risks and increase the accuracy and constancy of self-reporting by developing a standard survey instrument with closed- and open-ended questions that can be administered in an interactive manner directly by the researcher to the respondents [161], [162].

This research included administration of the CS-AF survey in a semi-structured and interactive fashion in efforts to minimize the variability that can arise with self-reporting. CS-AF surveys were delivered to each test participant electronically through the Qualtrics online portal; each section of the CS-AF survey was introduced to set the context of the section, followed by each specific question in a live video conference setting. This semi-structured approach accommodated participant questions and clarifications, as well as allowed for better explanation of the CS-AF survey questions and associated terms. The aim for this approach, although more time-consuming, was to capture as consistent and accurate information as possible from each respondent.

Each test participant completed an initial pre-test CS-AF survey (i.e., the blood pressure exam baseline), then was randomly assigned into one of two groups (Group 1: Manual BP Exam Workflow or Group 2: Technology-Mediated BP Exam Workflow). Test participants proceeded with a minimum 3-week clinical trial using the test protocol specific to each group. Following the 3-week trial test period, all test participants completed a second CS-AF survey with identical questions as the pre-test CS-AF (blood pressure exam baseline) survey, this time, pertaining to the 3-week trial.

3.2.2 CS-AF Statistical Basis and Analysis Procedure

The CS-AF survey data was collected for both the pre- and post- workflow trials for Group 1 and Group. The following analysis was conducted using the survey data:

1. **Data Processing:** CS-AF Survey data was cleaned and formatted into appropriate columniation for the subsequent statistical analysis using Minitab. This included the pairing of each randomly matched-pair in each record and in sequence with respect to each of the 5 workflow stages (when the workflow stages were used.)

2. **Test for Normal Distribution:** Matched-pair CS-AF survey data for each of the pre- and post-workflows for Group 1 and Group 2 was analyzed in Minitab using normal probability plot and Anderson-darling statistical test to assess whether the normality of the differences within each group was normal. The assumption was a normal distribution (approximately) of the difference between the paired values within each Group.

3. **Repeat measures ANOVA:** rANOVA calculations were conducted for each question, including each stage of the workflow (repeat measure) for analysis within group and between groups. Repeat measures ANOVA is a research design that supports the analysis of the same variable taken on matched subjects over two different time periods, as is the case with this study [163], [164], [165]. The independent variable is the blood pressure exam workflow, and the dependent

variable (or within-subjects factor) is the specific CS-AF question being analyzed within Groups. The CS-AF test design incorporates the same questions asked of the same groups for two different workflows at two separate times. Comparison of the CS-AF question for the baseline work is compared with the Manual or Technology-Mediated workflow (respectively for Group 1 and Group 2.) Repeat measures ANOVA is the ideal method to analyze the same group over multiple measures since variability can be eliminated from the analysis with the assumption of equality among all possible correlations between the test population, or sphericity [164].

rANOVA calculations were processed in Minitab, calculating the difference between mean values within Group 1 and within Group 2, and calculating the difference between mean values within Group 1 and Group 2. rANOVA results were analyzed identifying p-values <=.05 and through visual representation in box charts [166]. The specific layout and processing of the data processing for rANOVA is pictured below.

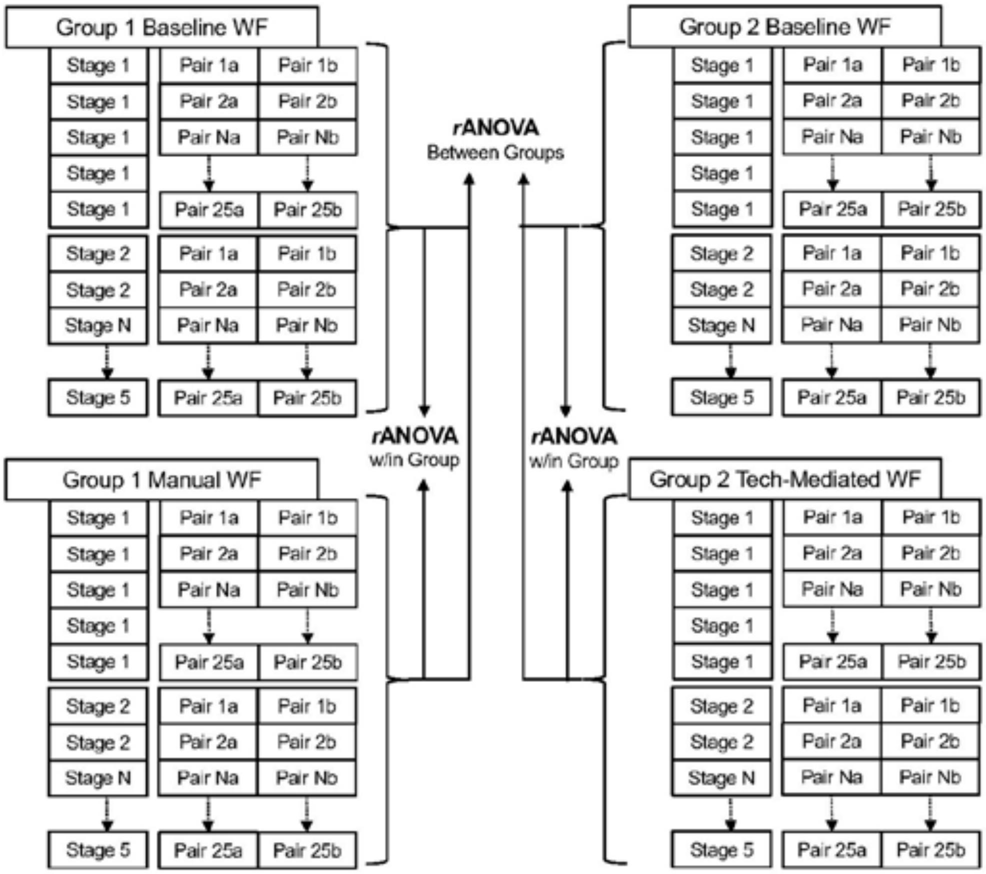


Figure 25: Repeat Measures ANONA (rANOVA) for CS-AF within Group and between Groups Analysis, Bondy 2020.

CS-AF survey questions for the Process, Technology, and Outcome sections were all designed to correspond with the specific stages in the workflow. (The BP exam workflow has 5 stages). The Context and Attitudes & Behavior sections of the CS-AF were designed to assess participant responses that reflect the overall workflow experience for key determinants recorded for the 4 workflows evaluated (i.e., GP1 and GP2 Baseline WF, GP1 manual, and GP2 technology-mediated workflows.)

4. **Analysis of Means:** Group means for each question were also calculated using Minitab; results data was analyzed and graphed using box charts.

5. **Matched-Pairs *t*-test:** For rANOVA analysis between and within Groups conducted in the previous Step 2 with p-values <=.05, subsequent matched-pairs *t*-tests were conducted to further understand the specific target workflow stage where the comparison of mean values in workflows is statistically significant. The matched-pairs *t*-test is an appropriate test when there is one measurement variable (in this research, a specific element of the CS-AF, such as time or attitude) and two nominal variables (of which, only one has two values.) For this research, there were multiple pairs of observations (25) and one observation for each combination of the nominal variables. For example, one nominal variable represented the test participant, and the other nominal variable represented two pairs of observations. The survey results from the current-state blood pressure exam (Test A) workflow and the survey results from both the manual BP workflow (Test Group 1) and the technology-mediated BP workflow (Test Group 2) were compared for this matched-pairs *t*-test [167].

   The matched-pair A-B *t*-test for each age/gender pairs was needed in order to test the hypothesis about the difference of the observation means between two groups–with and without the technology-mediated workflow. The paired *t*-test examined whether the mean difference in the pairs was different from 0. If the assumption of a normal distribution of the differences was unjustified, a non-parametric paired two-sample test, the Wilcoxon matched-pairs signed-ranks test, would be performed. If there was a normal distribution assumption, a two-sample paired *t*-test would be performed [167], [168], [169].

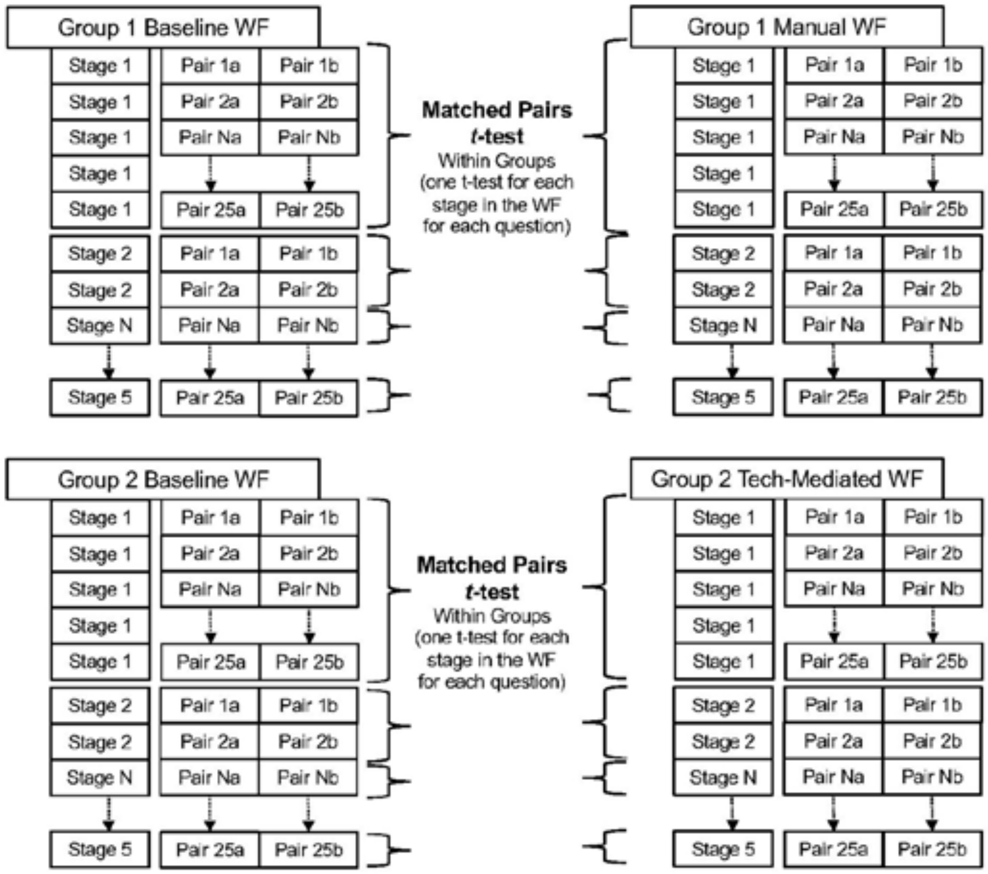


Figure 26: Matched Pairs t-test sequence, for CS-AF within Group Analysis, Bondy 2020.

3.4 Summary

The expanding role of computer technology in every aspect of our personal and professional lives demands that we develop a deeper understanding of collaborative workflows in all settings. The CS-AF introduces a unique approach for evaluating technology-mediated collaborative workflows using cross-disciplinary techniques to identify whether gains and gaps are a result of the workflow transformation.t

The CS-AF model and methodology were created to address three specific research questions and to validate the viability of this approach with two empirical studies. RQ1 was addressed in this section, and RQ2 and RQ3 will be addressed in the next sections.

RQ1: *What set of cross-disciplinary metrics and consistent methodology are necessary to effectively evaluate a technology-mediated collaborative workflow?*

RQ2: *Do the metrics and methodology introduced in the CS-AF produce an effective evaluation of the technology-mediated collaborative workflow for the graphic arts and hypertension workflows evaluated?*

RQ3: *Does the CS-AF and methodology deliver an effective generalizable approach to evaluate technology-mediated collaborative workflows across different domains?*

This research introduced the CS-AF model and methodology, and delivered two empirical studies where the CS-AF has been used. For each domain studied, there was targeted research that incorporated more specific emphasis on the nuances of that particular domain. For example, the graphic communications (GC) domain targeted research on the collaboration requirements; it presented the submitting of a sales quote request in the traditional manner (using a variety of manual inputs) versus the use of a smartphone mobile app (technology-mediated). The second empirical study examined a hypertension collaborative workflow in the Health Information Technology (HIT) domain focused on doctor-patient collaboration and the use of new technology to help facilitate blood pressure readings in a patient-centered healthcare approach. Previous to this research study, the CS-AF had been used for the CG workflow, then for this research study, it was proposed for use with the hypertension workflow. Both workflows from these very different domains were evaluated and compared using the CS-AF.

Chapter 4

CS-AF for Graphic Communications Workflow

4.1 Graphic Communications Workflow

Introduction

The Graphic Communications Workflow (GC) includes a comprehensive empirical study of a collaborative business-to-business workflow for a printing company that was looking to enhance the efficiency and experience between sales reps and project estimators to more effectively process sales quotations [148]. The Collaborative Space – Analysis Framework (CS-AF) was used to orchestrate, manage, and collect data from the existing workflow and the technology-mediated workflow associated with this empirical study.

This empirical study was conducted in Rochester, NY, at Cohber Press, a well-established printing company–not unlike other printing companies–seeking ways to improve accuracy and consistency, and to reduce the cycle-time associated with the collection of customer job specs and the accurate transfer of those job specs to the estimating department in order to generate a price quote.

The graphic communications industry is in constant flux. To orchestrate increasingly complex workflows that are built to deliver a variety of cross-media solutions, new technologies are incorporated into the workflow and new processes are introduced. Service providers such as Cohber Press have become systems integrators, judicially acquiring a wide-range of equipment and software to configure unique workflows that deliver differentiated services. The interpretation of market requirements, the deciphering of best-in-class systems, and the integration of these elements into an optimized workflow create high-stakes business concerns for service providers.

Making a good decision on the acquisition of equipment or a software solution does not guarantee that the value proposition of each will ultimately resonate with the market, nor contribute to the bottom line. The burden of technology selection and seamless integration into an optimized workflow falls largely on the shoulders of service providers. For service providers, as the complexity and diversity of technology required to deliver graphic communication services increases, so does the risk for realizing the value of their workflow investments.

Graphic communications workflows are typically built over time with two primary objectives: (1) the optimization of work processes (resulting in cost reduction), and (2) the introduction of new services (resulting in revenue growth). Optimizing workflow provides cycle-time benefit to both creators and service providers (i.e., producers), essentially presented as a time-saving benefit to creators and a cost-saving benefit to producers. Integrating new services provides expanded capability and features for creators and new revenue streams for producers.

Insights into the graphic communications industry and its workflows come from over 20 years of my experience as a practitioner and developer in the domain. It builds off of prior work focused on the analysis and modeling of current-state graphic communications workflows. Excerpts from this work led to the development and issuance of a workflow process and solutions engagement patent [6]. The prior research provides a foundational reference model (taxonomy) and seven use case workflow models that describe and catalog graphic communications and printing workflows. The graphic communications/printing workflows that were evaluated and encompass the primary traditional and emerging digital print workflows are:

- Static Offset Printing
- Hybrid Digital-Offset Printing
- Print-on-Demand
- Variable Data Printing
- Transactional Printing
- Web-to-Print
- Photo Services Printing

A deep understanding was gained from this in-depth ethnographic study of the graphic communications workflows (listed above) and, coupled with decades of domain knowledge, provided the foundational context to develop the CS-AF for targeted field use at a commercial printer site [6], [148].

The graphic communications industry has a rich history of workflow integration along these two precepts of workflow optimization and feature enhancement. In order to realize the value of these new innovations, each technological revolution has enabled a new wave of capability that needs to be interpreted by producers and, ultimately, to be synthesized into their operation for creators. Producers with expertise in monitoring emerging technology and incorporating new technologies into prototype and production workflows have a competitive advantage. To successfully keep pace with the complexity of new technologies introduced in this digital era, graphic communications service providers need the ability to integrate new technology into their workflows. Service providers such as Cohber Press are balancing scarce resources, both in time and capital; thus, they seldom commit the resources or the process regimen to step through a major technology integration with a systematic approach in order to validate the contribution of workflow investments.

Problem Statement

This workflow study was targeted at the Cohber Press' sales quote workflow, which includes a collaborative exchange between sales reps who are active in the field with customers and project estimators who are typically in-house. The sales quote process for Cohber Press, as with all printing companies, is both an extremely pivotal aspect of their operation and a workflow that is often plagued with errors and inconsistent information.

The sales quote process is the fulcrum point for the definition of work and the associated price that the printing company will charge for that work; essentially, it is the contract. Specific problems arise in the collection of customer job specs and the conveyance of those job specs to the estimators for processing, and then back to the customer in the form of a sales quote. Customers convey information regarding a job to a sales rep in a variety of descriptions, using any number of communications vehicles (email, test messages, voice mail, fax, etc.) with no standardized method of describing the job specs. The sales reps then collect the customer job spec information and relay that information to the in-house estimators, and in some cases, to a customer service rep and then on to the estimator. At each data exchange interval, errors in the capture and transfer of the accurate information exist; additionally, no standard data model was established to represent the required data. The current-state sales quote workflow at Cohber Press was riddled with errors, and they believed that the time from customer contact to final quotation was unacceptable to customers, causing loss of sales due to sales quote turn-around time. The sales quote process is a critical aspect of the Cohber Press operation, and thus was determined to be the high-priority collaborative workflow that Cohber was willing to analyze, improve with technology-mediated enhancements, and evaluate.

The leadership of Cohber Press determined that equipping their sales force and providing their clients with an automated cloud-based sales quotation system would increase their company's ability to be considered for more printing work than it would with their then-current sales quotation process. The goal for the technology-mediated collaborative workflow was to deliver a fast and interactive quotations system to empower print buyers to determine pricing as fast as possible, while increasing efficiency and accuracy within the Cohber Press team.

4.2 CS-AF Methodology: GC Workflow

The Collaborative Space – Analysis Framework (CS-AF) provides both a reference model and a structured analysis methodology to evaluate the association between current-state and technology-mediated collaborative workflows. The CS-AF comprises five key components that are designed to direct the consistent collection of important data points regarding workflow. When comprehensive baseline data can be collected for a current-state workflow and are then compared with the same data points for a technology-mediated workflow, a meaningful evaluation between the two workflows can be conducted.

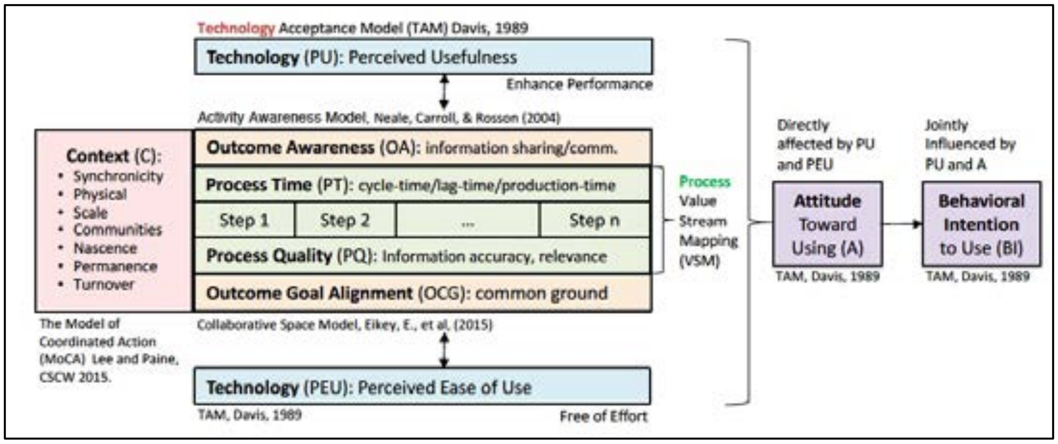


Figure 27: Bondy's Collaborative Space Analysis Framework, CS-AF V1

This pilot program incorporates the CS-AF structured framework and methodology to conduct a detailed workflow evaluation and comparison. The five elements of CS-AF are Context, Process, Technology, Behavior, and Outcomes (as shown in Fig. 27). An integrated semi-structured, mixed-methods (qualitative and quantitative) survey instrument has been developed as part of the CS-AF. This specific survey instrument is incorporated at two intervals within this study: at the start prior to any changes (current-state) and at the completion of the technology-mediated enhancement. The final step in the CS-AF methodology is a comparison of the pre- and post-enhanced workflow analysis to determine how effectively the problems identified in the current-state workflow have been addressed.

The CS-AF methodology includes five sequential steps that are followed in series by completing all the aspects of one step before moving on to the next step in the sequence. The five steps used in the CS-AF methodology for the Cohber Press collaborative workflow study are:

1. Current-State Workflow Definition and CS-AF Survey Refinement
2. CS-AF User Survey and Current-State Workflow Analysis
3. Technology-Mediated Enhancement – Development and Field Implementation

4. CS-AF User Survey – Technology-Mediated Collaborative Workflow Analysis
5. CS-AF Collaborative Workflow Analysis – Evaluation between Current-State and Technology-Mediated Workflow

CS-AF Step 1: Workflow Definition and Qualitative/Quantitative Survey Refinement

The initial step in the research with Cohber Press, following the CS-AF methodology, was to identify and document the specific process steps that are required for ITS current-state sales quote workflow. Each workflow step is considered to be a discrete segment of the workflow that requires an action (input, process, and output) and advances the process forward to the next logical juncture in the sequential process, from start to finish. Defining the process steps is an import aspect of the CS-AF approach, as it provides the structured steps necessary for development of the qualitative and quantitative survey and data collection materials for this specific sales order workflow at Cohber Press.

The survey design is also a critical step in the CS-AF methodology, since the survey instrument is custom-designed for each workflow and is used to collect all workflow information that is included in Step 2 and Step 3 of the CS-AF methodology. Designing the survey instrument based on the CS-AF and the specific workflow process steps at Cohber Press provided a consistent methodology to evaluate and record all important aspects of the current-state and future-state workflow

Through on-site ethnographic workflow analysis, it was determined that current-state sales quote process at Cohber Press consists of ten discrete workflow steps (as shown in Fig. 28). The specific workflow steps had been identified and documented using VSM, and verified with the Cohber Press team to ensure that they reflect an accurate portrayal of the existing workflow.

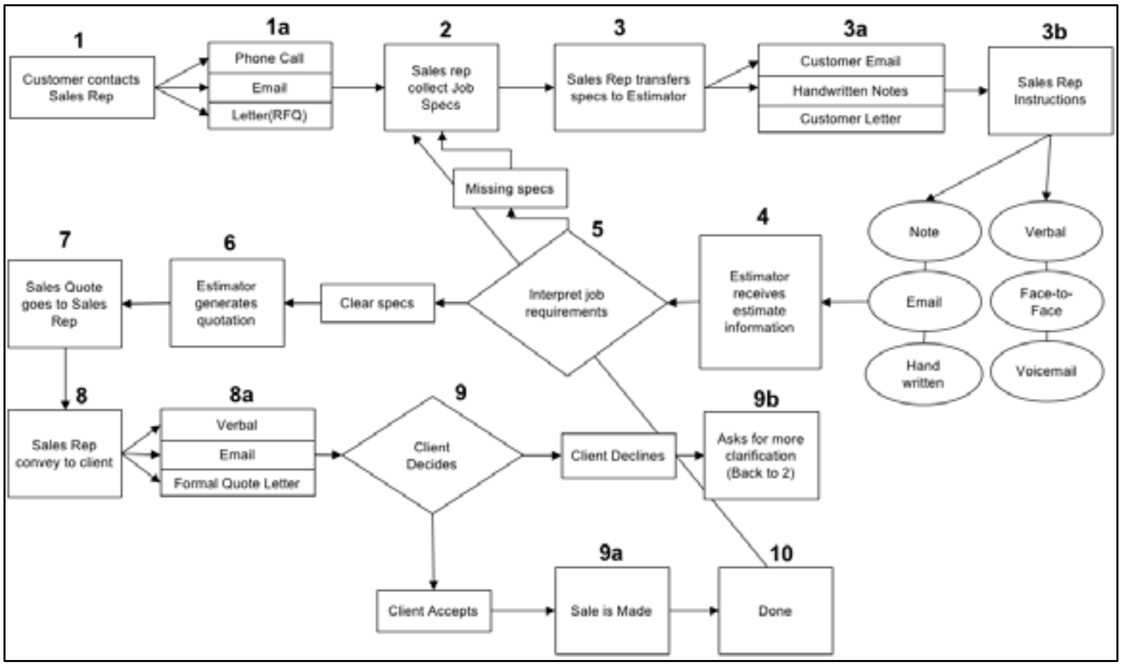


Figure 28: Cohber Press 10-step current-state workflow

The field analysis conducted in Step 1 of the CS-AF method established the specific workflow steps that were incorporated into the CS-AF survey instrument for data collection and analysis of the current-state sales quote workflow in Step 2. Through this effort, it was determined that five Cohber employees from four different departments would participate in the comprehensive CS-AF analysis for both pre- and post-workflow enhancements.

CS-AF Step 2: User Survey and Current-State Workflow Analysis

The initial analysis of Cohber's current-state sales quote workflow identified a number of specific issues and opportunities for improvement that supported the original problem statement. Specifically, the process uncovered three target areas that represented the significant gaps in the workflow.

1. Inconsistent collection of customer job order specifications
2. Inconsistent transfer of customer job order specs within Cohber Press
3. Time-consuming and somewhat cumbersome process from customer input to final sales quote

These specific problems identified in the current-state analysis were the primary target areas for the technology-mediated enhancements that were conceptualized, vetted with Cohber Press, and ultimately implemented in Step 3 of the CS-AF.

CS-AF Step 3: Technology-Mediated Enhancement – Development and Field Implementation

The goals for the technology-mediated enhancements at Cohber Press were focused on improvements to data quality and reduced cycle time. The development efforts were designed to collect accurate customer job spec data, transfer that data consistently within Cohber's operation, and facilitate a more streamlined workflow to reduce the time required to process an estimate. In efforts to comprehend the requirements and detailed specifications required for a sales quote, a dynamic sales quote form was developed. The dynamic sales form was used as a consensus building tool to define a standardized set of job parameters that could be used to define the majority of jobs that Cohber Press encounters. Through iterative work, the dynamic sales quote form was completed and operationalized as a semi-automated means of collecting consistent customer job specs and communication of those specs within the Cohber Press operation. Development of the dynamic sales quote form for use with the current workflow proved to be a very useful intermediate step in defining a more universal approach to collect and collaboratively process the customer request for a sales quote.

Once the dynamic sales quote form was integrated into the operation, development work began on a cloud-based mobile application to incorporate the standardized job spec data into a streamlined collection process that incorporated all collaborative participants in the workflow. The sales quote app was developed, tested, and implemented at Cohber Press. The original five Cohber employees assigned to this project were trained, so that they could use this new sales quote system in their routine efforts with live customers. In the next section, details regarding the enhanced technology-mediated development effort are described.

CS-AF Step 4: User Survey – Technology-Mediated Workflow Analysis

Following the development and testing of the new sale quote app at Cohber Press, a re-evaluation of the workflow was performed using the CS-AF. This survey process required a reassessment of the Cohber sale quote workflow from the new perspective of the technology-mediated workflow, incorporating the same CS-AF approach and with the same users who had participated in the initial current-state workflow analysis.

The use of technology to enhance the sales quote workflow introduced an immediate and significant change. By virtue of some specific steps being combined or eliminated (due to the immediate efficiencies evidenced in the enhance workflow), the current-state 10-step workflow process was then condensed to a 7-step sales quote process (as shown in Fig. 29).

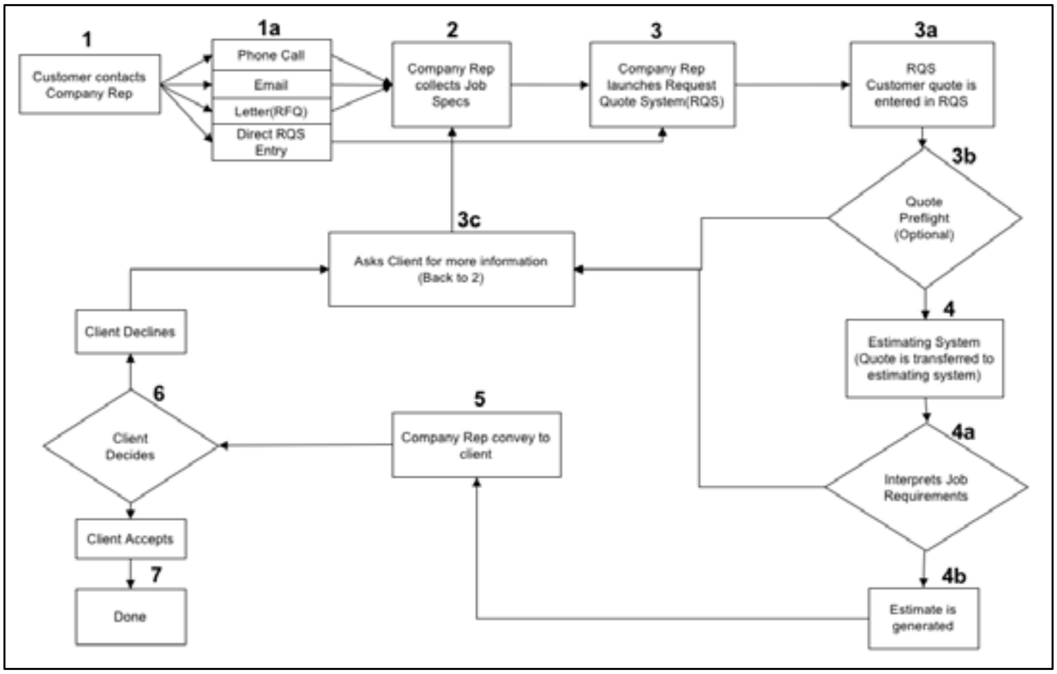


Figure 29: Cohber Press 7-Step Technology-Mediated Sales Quote Workflow

A complete technology-mediated collaborative workflow analysis using the CS-AF was conducted onsite at Cohber Press with the original five employees who had participated in the initial current-state workflow analysis. The CS-AF survey data from the current-state and from the technology-mediated workflow were then evaluated, and the results were analyzed in the next, and final, step of the process.

CS-AF Step 5: Collaborative Workflow Analysis – Evaluation Between Current-State and Technology-Mediated Collaborative Workflow

CS-AF survey data from both the initial (current-state) workflow and the technology-mediated collaborative workflow were evaluated and compared, and the results were tabulated and analyzed. The analysis using the CS-AF delivered a true cross-disciplinary view of collaborative workflow with a number of significant insights that might have otherwise gone unrecognized without the use of the CS-AF. Specifically, the CS-AF delivered quantitative data that could be further calculated to represent viable business metrics which were of high interest to the Cohber Press leadership team. The CS-AF also brought to life attitudinal and behavior aspects of the enhancement that would suggest progress. However, it also raised concern that the training of and transition by Cohber employees to the new workflows, although familiar, may be error-prone.

Complete test results and analysis is covered in the subsequent sections of this chapter, including lessons learned that were applied to improvements to the CS-AF for the second empirical study, the doctor-patient hypertension collaborative workflow.

4.3 GC Technology-Mediated Collaborative Workflow

The technology-mediated collaborative workflow that was developed for this study for Cohber Press incorporates a secure cloud-based mobile app infrastructure, with a streamlined user-interface that steps Cohber users through the sales quote process. (Fig. 30 illustrates this technology-mediated workflow.) The enhanced system also provides messaging, transfer of quote specs to the quotation database, and statistics that can be harvested for future informatics analysis.

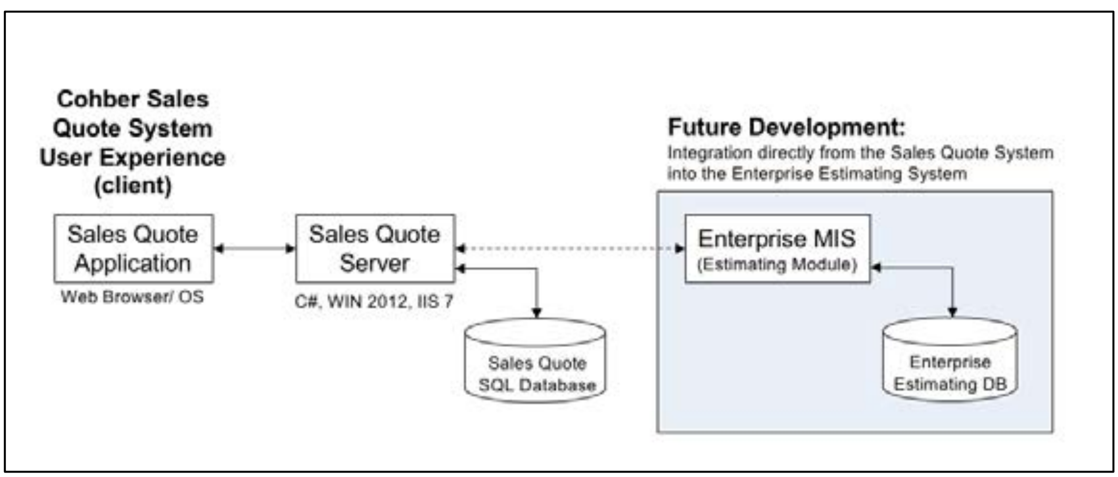


Figure 30: Cohber Press Technology-Mediated Workflow Development Model

An iterative and agile software development process was followed for the software development aspects of this study. Cohber Press has previous software development initiatives that were based on a Microsoft Windows, C#, and SQL database architecture; therefore, this development effort followed the same path. The development process included four discrete steps: design and definition, development, workflow integrate, and test/validation of the specific workflow enhancements that were aimed at optimization or expanded capability to the workflow.

When the development and testing were completed, users were introduced to the new technology-mediated workflow through group training, followed by real-time resolution of user specific issues. In order to resolve issues and refine system functionality based on the team consensus of best practices, several iterative software releases of the technology-mediated workflow were released during the early adoption of the new workflow.

4.4 Results and Analysis

The following data analysis reflects the information collected through the CS-AF at Cohber Press from both the current-state and technology-mediated surveys that were conducted. The summary results of the three primary research hypothesis is followed by the detailed results of the secondary hypothesis H1.1-H1.12.

Primary Hypothesis H1: *It is hypothesized that the CS-AF will produce* ***consistent data from a diverse set of parameters that will deliver a meaningful comparison*** *between the current-state and technology-mediated workflows evaluated.*

Primary Hypothesis H1 proved valid that the CS-AF enable an initial view of the workflow as a snap-shot in time of a complete and diverse set of data that facilitated a thorough bassline understanding of the workflow. The context, and time-series data enabled a measurable reference with respect to gains and gaps achieved with the technology-mediated workflow. The CS-AF also enabled a complete view of user perspectives regarding both workflows including valuable insights with regards to attitude, behavior, goal alignment regarding the two workflows. Group mean data was evaluated from all CS-AF survey questions and the mean values were compared to assess the gains and gaps of the two workflows evaluated.

	Primary Hypothesis Description H1	**GC WF** False/Valid
H_0 Null Hypothesis ц BLWF = ц TMWF	The CS-AF does not deliver a consistent data from diverse metrics to effectively evaluate collaborative technology mediated workflows.	
H_a Alternative Hypothesis ц BLWF != ц TMWF	The CS-AF does deliver a consistent data from diverse metrics to effectively evaluate collaborative technology mediated workflows.	Valid

Primary Hypothesis H2: *It is hypothesized that the CS-AF will produce an* ***effective approach*** *(model and methodology) that can be used to evaluate current-state workflow and a technology-mediated collaborative workflow for the Graphic Communications domain.*

Primary Hypothesis H2 also provide valid, with some caveats to consider. The CS-AF proved to be a valid approach with respect to the CS-AF survey and field engagement methodology, which was a key objective of this initial pilot program. The CS-AF survey instrument worked as intended and enabled the accurate collection of data for the two intervals of the workflow studied. The field engagement process also proved to be valid and facilitated an organized and consisted method to interact with live users and collected important pre-post workflow data. There is however room for improvement in the administration of the CS-AF survey instrument, and most importantly there is need for more statistical rigor necessary to identify significant changes in the workflow from the pre- to post analysis. These two caveats shape the direction for further investigation and refinement to the CS-AF for future work.

	Primary Hypothesis Description H2	**GC WF** False/Valid
H_0 Null Hypothesis цBLWF = цTMWF	The CS-AF does not deliver a cross-disciplinary set of metrics to effectively evaluate collaborative technology mediated workflows.	
H_a Alternative Hypothesis цBLWF != цTMWF	The CS-AF does deliver a cross-disciplinary set of metrics to effectively evaluate collaborative technology mediated workflows.	Valid

Primary Hypothesis H3 Generalizable Hypothesis: *It is hypothesized that versatility of the CS-AF will be viable as* ***a generalizable analysis approach*** *for the GC workflow. It is further hypothesized that the CS-AF can be adapted to other domains where technology-mediated collaborative workflow is required.*

Primary Hypothesis H3 proved false based on the lack maturity of the CS-AF and associated methods at this stage of development. Specifically, the CS-AF needs a more structured and formal statistical method to ensure replicability, this includes data analysis, summary statistics, and automation. The CS-AF survey instrument would also need to me automated into a web-based survey instrument to facilitate better data capture and a more streamlined integration the data analysis process. The CS-AF methodology needs to include an automated process to collect, analyze, and observe the statistical significance associated with group responses to the CS-AF survey questions. Using t-test and ANOVA analysis of the parametric and time-series data collected from the CS-AF survey will enable statical discernment with regard to the significance of the change in the user perspective of the workflow from the baseline to the technology-mediated workflow (difference in mean values per determinant). For the CS-AF to be considered a generalizable approach that could be transformed to multiple domains, further research is needed to expand the methodology to be robust enough for other researcher to be able to replicate the statistical and summary results to compliment the field engagement and CS-AF survey content that were acceptable.

	Primary Hypothesis Description H3	**GC WF**
		False
H_0 Null Hypothesis ꞵBLWF = ꞵTMWF	The CS-AF does not deliver a cross-disciplinary set of metrics that can be effectively transformed as a generalizable approach to evaluate collaborative technology mediated workflows.	False

Each component of the CS-AF (Context, Process, Technology, Behavior, and Outcomes) was collected, evaluated, and analyzed. The specific comparative evaluations (mean data per CS-AF determinant) for each attribute of the five elements of the CS-AF for the Cohber Press sales quote workflow are summarized in the right column of each entry in the tables below. This empirical study was designed as a prototype evaluation of the CS-AF in live field conditions, there were a limited number of test participants and the statistical analysis was simplified to time series data, and comparison of mean values for each CS-AF determinant. Summaries of the relationship between the current-state and the technology-mediated collaborative workflow are shown in Tables 8 – 12.

CONTEXT	Current-State	Technology-Mediated	Analysis
H1.1: It is hypothesized that technology-mediated workflows are more asynchronous and remote, when compared with current-state workflows. *Null Hypothesis is valid (*ꞵBLWF = ꞵTMWF) = *workflow is not more asynchronous*			
Synchronicity	Synchronous/Mixed	Synchronous/Mixed	No change
Physical Distribution	Mixed	Mixed	No change
Scale	5 people	2 People	Reduce involvement of 3 people
Communities	4 Departments	2 Departments	Eliminated participation of 2 departments

CONTEXT	Current-State	Technology-Mediated	Analysis
Nascence	Routine	Developing	New emerging workflow
Planned Performance	Long-term	Long-term	No change
Turnover	High	Low	Reduced iterations in and out of the workflow

Table 8: Context analysis between current-state and technology-mediated workflow

<table>
<tr><th>PROCESS</th><th>Current-State</th><th>Technology-Mediated</th><th>Analysis</th></tr>
<tr><td colspan="4">H1.2: It is hypothesized that technology-mediated workflows are more streamlined (i.e., require less time), when compared with current-state workflows.
Alternative Hypothesis is Valid (ɥBLWF != ɥTMWF) = substantially less time
H1.3: It is hypothesized that technology-mediated workflows deliver better information quality, when compared with current-state workflows.
Null Hypothesis is valid (ɥBLWF = ɥTMWF) = only slight info quality improvement</td></tr>
<tr><td>Number of Steps</td><td>10 Steps</td><td>7 Steps</td><td>3 Steps eliminated</td></tr>
<tr><td>Total Minimum Production Time (cycle time - all tasks)</td><td>3,346 min.
55.76 hrs.
2.32 days</td><td>1,545 min.
25.75 hrs.
1.07 days</td><td>Cut minimum production time more than in half (53.8%)</td></tr>
<tr><td>Total Maximum Production Time (cycle time - all tasks)</td><td>14,553 min.
242.55 hrs.
10.11 days</td><td>3,440 min.
57.3 hrs.
2.38 days</td><td>Cut maximum production time more than three-quarters (76.5%)</td></tr>
<tr><td>Production Time Rating</td><td>Neutral to Unacceptable</td><td>Slightly to
Very Acceptable</td><td>Increased production time rating one-and-a-half categories</td></tr>
<tr><td>Process Quality Rating (quality/accuracy of info.)</td><td>Slightly Important to
Very Important</td><td>Very Important to
Slightly Important</td><td>Slightly better information quality for technology-mediated workflow</td></tr>
</table>

Table 9: Process analysis between current-state and technology-mediated workflow.

<table>
<tr><th>TECHNOLOGY</th><th>Current-State</th><th>Technology-Mediated</th><th>Analysis</th></tr>
<tr><td colspan="4">H1.4: It is hypothesized that technology-mediated workflows are perceived to be more useful, when compared with current-state workflows.
Alternative Hypothesis is Valid (ɥBLWF != ɥTMWF) = substantially more useful
It is hypothesized that technology-mediated workflows are perceived to be easier to use, when compared with current-state workflows.
Alternative Hypothesis is Valid (ɥBLWF != ɥTMWF) = substantially more, easy to use
Note: CS-AF was expanded following the GC empirical study to include three additional evaluation metrics: Satisfying, East to Learn, and Promotability – These metrics have been added to the CS-AF are included in the proposal for the second empirical study, Dr. -patient collaborative hypertension workflow.</td></tr>
<tr><td>Perceived Usefulness: How useful is the Technology used in the workflow?</td><td>Slightly Useless</td><td>Slightly Useful</td><td>Moved two levels more useful</td></tr>
<tr><td>Perceived Usefulness: Do you feel Technology can enhance usefulness?</td><td>Slightly Likely that the workflow can be enhanced</td><td>Slightly Likely that the workflow can be enhanced</td><td>Users perceived improvements can be enhanced from current-state to technology-mediated workflow</td></tr>
<tr><td>Perceived Ease-of-Use: How useful is the Technology used in the workflow?</td><td>Slightly Useless</td><td>Slightly Useful</td><td>Moved two levels more useful</td></tr>
<tr><td>Perceived Ease-of-Use: Do you feel Technology can enhance ease-of-use?</td><td>Slightly Likely</td><td>Very Likely</td><td>Moved one level more likely that the technology can enhance ease-of-use</td></tr>
</table>

Table 10: Technology analysis between current-state and technology-mediated workflow.

<table>
<tr><th>ATTITUDE & BEHAVIOR</th><th>Current-State</th><th>Technology-Mediated</th><th>Analysis</th></tr>
<tr><td colspan="4">It is hypothesized that the attitude to use technology-mediated workflows is more positive, when compared with current-state workflows.
Alternative Hypothesis is Valid (ɥBLWF != ɥTMWF) = attitude to use improved
It is hypothesized that the behavioral intention to use technology-mediated workflows is more positive, when compared with current-state workflows.
Alternative Hypothesis is Valid (ɥBLWF != ɥTMWF) = behavioral intent to use improved</td></tr>
</table>

ATTITUDE & BEHAVIOR	Current-State	Technology-Mediated	Analysis
Positive opinion regarding the workflow	No	Yes	Users have more positive attitude toward technology-mediated workflow
Perceives that using the workflow is good for them	No	Yes	Users perceive that the technology-mediated workflow is better for them
Perceives that using the workflow is appropriate for them	No	Yes	User perceive that the technology-mediated workflow is more appropriate for them
Intend to use the workflow in the next week	Yes	Yes	Users intend to use both workflows
Expect to continue to use the workflow in the future	No	Yes	Users expect to use the technology-mediated workflow in the future

Table 11: Attitude and Behavior analysis between current-state and technology-mediated workflow.

<table>
<tr><th>OUTCOMES</th><th>Current-State</th><th>Technology-Mediated</th><th>Analysis</th></tr>
<tr><td colspan="4">It is hypothesized that technology-mediated workflows increase the awareness of information sharing needs, when compared with current-state workflows.
Alternative Hypothesis is Valid (μBLWF != μTMWF) = goal awareness improved
It is hypothesized that technology-mediated workflows increase goal alignment, when compared with current-state workflows.
Alternative Hypothesis is Valid (μBLWF != μTMWF) = goal alignment improved</td></tr>
<tr><td>How aware do you feel people are with your goals?</td><td>Slightly Unaware</td><td>Slightly Aware</td><td>Technology-mediated workflow is two levels more aware of users' goals</td></tr>
<tr><td>How likely does the info quality meet your needs?</td><td>Neutral to Slightly Unlikely</td><td>Slightly Likely</td><td>Technology-mediated workflow is two levels improved on info quality</td></tr>
<tr><td>What is your primary goal for the workflow?</td><td>Quote/estimate to win business revenue
Efficiency and accuracy</td><td>Efficiency and accuracy
Quote/estimate to win business revenue</td><td>Goals swapped in priority based on implementing a new workflow</td></tr>
</table>

OUTCOMES	Current-State	Technology-Mediated	Analysis
How aligned do you feel people are with your goals?	Neutral (neither aligned nor misaligned)	Slightly Aligned	Technology-mediated workflow is one level improved on goal alignment

Table 12**:** Awareness and Goal Alignment analysis between current-state and technology-mediated workflow.

Using the CS-AF model and methodology to determine the association between current-state and technology-mediated collaborative workflow proved to be an effective process for Cohber Press that yielded valuable qualitative and quantitative insights.

> *The automated sales quote system facilitates faster, more accurate quotes and instills a level of discipline in areas where we lacking control* (Cohber Press President).
>
> *The sales quote system is not as easy as the way I used to send sales quote requests, but I am very pleased that I get my quotes turned-around faster, and the extra time it takes to prepare the quote request is worth the time* (Cohber Press Sales Rep).
>
> *It is great getting quote request in a standard format – I can see right away if there is info missing, so I know how to follow-up, never thought we'd get the Sales Reps to follow a standard process, but I love it*! (Cohber Press Customer Service Rep).
>
> *On the new system, the information that I am starting with to produce a sales quote is so much more complete – allows me to turn estimates out quicker, I would really like these quote request to automatically flow right into the estimating system in the future!* (Cohber Press Estimator).

The CS-AF delivered a structured and comprehensive approach to measure improvements to the workflow that could be translated to meaningful business terms. The CS-AF provided unique visibility to the value gained through the technology-mediated development invested in the future-state workflow, compared to the "as-is" or current-state workflow. Through the quantitative analysis, the CS-AF was able to demonstrate true return on investment (ROI) data, as well as qualitative behavioral insights into the receptibility of the new workflow from the viewpoint of intended users.

The following summary points were derived directly from the use of the CS-AF model and methodology:

- Cohber optimized their workflow and substantiated their development investment. They reduced their minimum production time by 53.8% (from 2.3 days to 1.07 days) and maximum production time by 76.5% (from 10.11 days to 2.38 days). Optimizing workflow and reducing production time is paramount for Cohber Press; with a daily gross revenue budget of $36,900 per day, delivering finished goods to clients in less time has a direct and positive impact on the company's cash flow. The optimization gained in sales quote cycle time proved to provide meaningful business value to Cohber Press.

- Using the CS-AF, Cohber was able to identify design gaps and optimization opportunities, refine their sales quote workflow, and quantify specific future improvements that are required.

- Using the CS-AF helped Cohber to better understand the context of the workflow, attitudes, and behavior of users. These insights helped advance user adoption and overall user satisfaction.

- Documenting, qualifying, and quantifying the benefits of technology-mediated collaborative workflow provided insights into the cost/benefits of the workflow investment benefits and helped everyone to comprehend the value of the technology-mediated workflow development effort.

Although the overall results of the CS-AF model and methodology were positive both from the Cohber Press perspective and from the data that the CS-AF delivered, this first-time field experience using the CS-AF generated some issues and areas for improvement. Learnings from the first empirical study are summarized in the following section. Specific modifications to the CS-AF were made prior to conducting the second empirical study.

4.5 Learnings

The aim of the CS-AF is the creation and use of a generalizable model and methodology to direct a measurable comparison and evaluation of collaborative workflows. Testing the CS-AF in an empirical study at Cohber Press was an extremely valuable experience that uncovered a number of areas for improvement that will make the CS-AF easier to deploy and also to deliver more comprehensive evaluation data. Two themes emerge from the workflow study that warranted revisions to the CS-AF prior to embarking on the second workflow study; these themes were improvements to the ease and efficiency of the CS-AF survey instrument, and expanded data collection with respect to ease-of-use, perceived usefulness, ease-of-learning, and satisfaction.

First, the CS-AF survey instrument used in the first workflow study could be more streamlined, such that the field data collection process is simplified and more intuitive both for test participants and for the researcher. The CS-AF is comprehensive approach to evaluating collaborative technology-mediated workflow and, as such, involves a certain level of structure and rigor that needs to be followed in order to achieve useful results. Streamlining the CS-AF survey tool, such that the survey is formatted and organized for minimal data collection time, is important. Specifically, all test question scripts are embedded into the survey tool, are highlighted in bold, and appear in the precise order of data collection. All participant data collection is formatted in the CS-AF survey instrument, facilitating ease and accurate collection and recording. Likert scale values are circled, numeric values entered, and collected qualitative feedback is noted in sequence, etc. Refinement of the CS-AF to be more researcher-friendly for the interactive survey and data collection would help streamline the data collection process and interaction with test participants. These specific changes were made to the CS-AF survey instrument for use in the second workflow study.

Secondly, when the survey data from current-state and technology-mediated workflows was collected and analyzed for the first workflow study, it was somewhat difficult to portray the data collection results specifically for the Technology aspects of the CS-AF. Participants responded well to the questions, yet the results did not yield the detail that was expected. Upon further research, it was determined that the CS-AF could easily be expanded to included survey questions and metrics that would render better quantitative representation of participants disposition specifically for the following areas: Ease of Use, Perceived Usefulness, Ease of Learning, and Satisfaction. Gaps in the data representation for these areas could specifically be addressed by including the USE survey [26] in the CS-AF. An example of that representation is shown in Fig. 31.

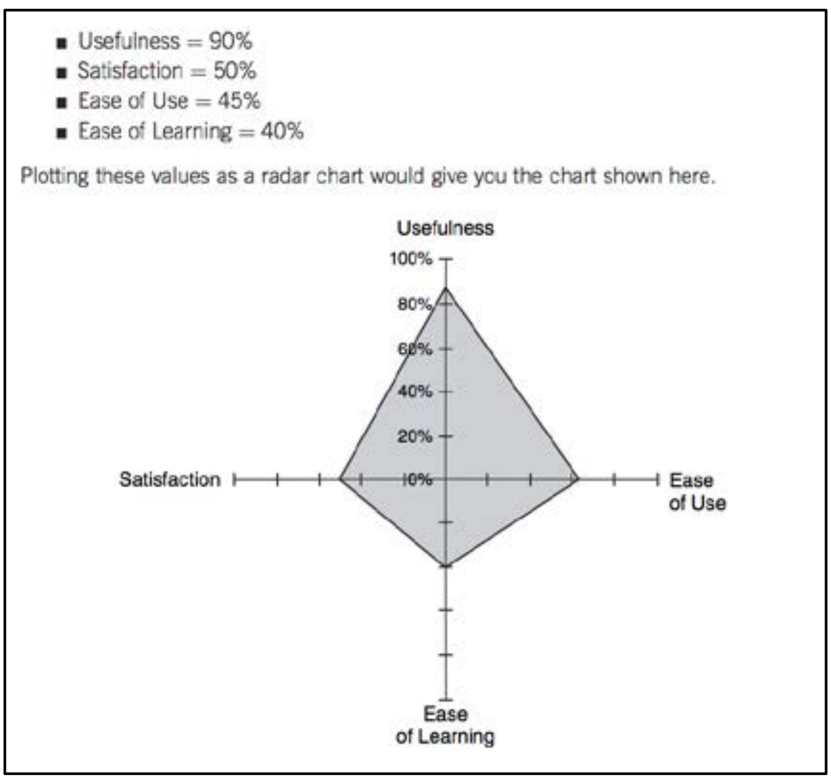


Figure 31: The System Usability Scale (USE)

The USE survey instrument (described in the Related Works section) was developed by Lund [26]. Essentially, it is a more comprehensive survey instrument addressing Ease of Use, Perceived Usefulness, Ease of Learning, and Satisfaction rating of participants, with the resulting data visualization represented in a radar chart. This additional component to the CS-AF enables a more comprehensive and comparative view of not only each of these aspects of technology adoption by participants, but also the delivery of a comparative and visual representation of these four aspects together in one radar chart.

It was also determined that the CS-AF could be further improved with the addition of another simple evaluation component that would fortify the Behavior aspects of the CS-AF, specifically adding the Net Promoter Scale™ [27].

The addition of the NPS to the CS-AF complements other metrics by extending the Behavior component to measure how likely users are to promote the product to others in their circle of influence. The goal of the NPS is to measure the overall perception of a brand/product/workflow and is complementary to other CS-AF metrics such as USE and TAM. Respondents are asked to rate their likelihood of promoting the workflow on a scale of 0-10 (not at all likely to extremely likely). People scoring from 9 to 10 are considered to be Promoters, users who will "keep buying and refer others." Those scoring from 7 to 8 are considered Passives who are vulnerable to competitors. Those scoring 0 to 6 are considered Detractors who are unhappy customers that can damage a brand through word-of-mouth. The percentage of promoters minus the percentage of detractors will return a Net Promoter Score [27].

The addition of these components to the CS-AF and the streamlining of the CS-AF survey instrument come as a direct result of learning from the first workflow study. The revised CS-AF introduced in the prior section and used for the second workflow study is illustrated below in Fig. 32. The CS-AF V2 was used with the refined CS-AF for the Hypertension collaborative workflow study, discussed in the next section.

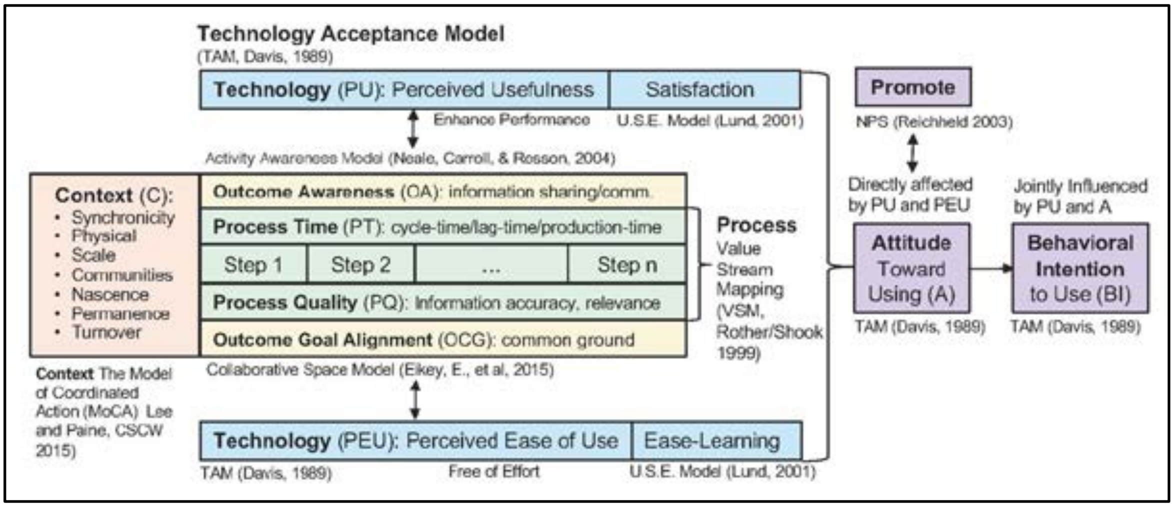


Figure 32: Bondy's Collaborative Space - Analysis Framework, CS-AF V2

All other aspects of the CS-AF were well integrated and delivered the expected and acceptable results. The contextual view and comparison of the workflows were well captured using the MoCA approach. Incorporating VSM in the CS-AF delivers extremely valuable quantitative data that ultimately drove the financial information that was of very high interest to Cohber Press. Incorporating the evaluation of participants goals also expanded the perspective of the TAM model, which has proved to be a solid foundational component of the CS-AF.

Finally, learnings from the initial GC collaborative workflow study using the CS-AF also unscored the need for more detail concerning the explanation of the statistical approach and justification of the analysis methodology with respect to a robust and generalizable framework. For the subsequent hypertension collaborative workflow study, more details will be provided regarding the CS-AF statical procedures, analysis methodology, including the CS-

AF summary metrics, explanation and justification of the analysis and the comparative approach between the pre-post collaborative workflows.

Chapter 5

CS-AF for Hypertension (at home) Blood Pressure Exam Workflow

5.1. Hypertension Exam Workflow

Introduction

Included in this research is a second empirical study targeted at the Health Information Technology (HIT) domain, specifically addressing a hypertension exam workflow, or the collaborative workflow between doctors and patients for blood pressure testing. One of the objectives for this workflow study was to establish further validation of the CS-AF as generalizability model and methodology to evaluate collaborative technology-mediated workflows in a variety of domains.

The HIT domain is under constant transformation with frequent introduction of new technologies that clinicians and patients must reconcile in order to maximize the benefits that new innovations offer. HIT is a high-stakes domain requiring the integration of new software and hardware technologies, as well as portals, data, informatics, etc. Workflows in the HIT domain are often complex workflows that must be secure–and proven–since reliance on technology is becoming foundational to clinicians at all levels. An overarching theme in the

HIT domain is the focus on patient-centered care. As a goal, this incorporates the use of new technologies (largely through software solutions) that are aimed at a reduction in hospital visits and re-admissions through proactive participation from patients. Winbladh et al. state that "patient-centered healthcare puts responsibility for important aspects of self-care and monitoring in patients' hands, along with the tools and support they need to carry out that responsibility" [31:1].

Collaborative workflows supporting patient-centered healthcare involve tightly coupled integration of technology between doctors and patients. From the system-wide adoption of Electronic Health Records (EHRs) through patient portals, to the incorporation of new microsensing technologies that provide real-time patient data, the HIT domain is both positively and negatively impacted by new technologies. With the growing number of personalized microsensor devices available, further integration complexity is introduced for doctors and patients alike.

Smart microdevice wearable technology is defined as a technology that can be worn and that has the capability to communicate autonomously and process information in real time [170]. With the compound annual growth rate for the wearable market projected at over 17% and over $14 billon USD in 2018, wearables are here to stay [171]. Despite the growth and consumer enthusiasm, concerns regarding the validity and interpretation of the data from wearables exit. Although wearables provide microdata on patient activities, the data are often not directly communicated to the clinicians, nor integrated with other data for better insights. The use of microsensors by patients further complicates doctor-patient collaboration, since many of these devices are not doctor-vetted, nor are they integrated with clinical workflows.

The research of Fritz et al. extends the use of sensing devices for personal activity; it found a true affinity for microdata with participants. "Most participants reported that the use of the device had motivated or helped them make durable changes" [37:491]. Doctors, however, are not comfortable with data from microsensors for a number of reasons. For doctors and other clinicians, microsensor devices are not familiar to them. The devices often are not certified by the governance organizations that they rely on for tested validation, nor is the data integrated into the systems that clinicians use on a routine basis. These gaps in the workflow present an enormous obstacle for doctors working with patients that are steeped in unvetted microsensor data.

Neel Chokshi, MD, is the Director of the Sports Cardiology and Fitness Program at Penn Medicine's research team which studied the relationship between consumers and their wearable devices [172]. Chokshi stated, "we haven't really told doctors how to use this information. Doctors weren't trained on this in medical school" [173: 2]. Clinicians across the HIT domain express concerns regarding wearables [174]. Andrew Trister, MD, an oncologist at the nonprofit medical research organization, Sage Bionetworks, states, "I'm an oncologist, and I have these patients who are proto 'quantified self' kinds of people…They come in with these very large Excel spreadsheets, with all this information – I have no idea what to do with that" [174].

Compounding the barrage of microdevice data, doctors are investing a considerable amount of time counseling patients on health-related web-surfing information; 53% of internet users 18-29 years old and 71% of users 50-64 years old have gone online for health information [175]. Research conducted by Helft, a physician at the University of Indiana, found that "when a patient brings online health information to an appointment, the doctor spends about 10 extra minutes discussing it with them" [33].

Software is becoming increasingly important in patient-centered healthcare, and software-intense systems are likely to become integral in prescribed treatment plans [31].

Critical to the success of patient-centered healthcare software and tools is an understanding of the collaboration preferences between patients and doctors in a variety of contexts. Researchers need to incorporate doctors and clinicians of all types into their research in order to bridge the widening gap that new technologies have introduced.

Piwek et al. posit that “moving forward, practitioners and researchers should try to work together and open a constructive dialogue on how to approach and accommodate these technological advances in a way that ensures wearable technology can become a valuable asset for health care in the 21st century [176]. In the research of consumers’ adoption of wearable technology, Kalantari et al. suggest that future research should test “demonstrability” (i.e., whether the outcome of using the device can be observed and communicated,) mobility, and the experience of flow and immersion when using these devices [177].

The objective for this research is to utilize the CS-AF and methodology to evaluate doctor-patient collaborative workflow for hypertension by using a blood pressure device and a smartphone app that is common to doctors, and most importantly, by incorporating doctors and their patients in this empirical study. This research and empirical study included the documentation and analysis of the current hypertension workflow for a set of patients and two medical doctors using the CS-AF, the development and integration of a technology-mediated workflow that would be introduced to the same set of users, and the analysis of both the current and technology-enabled workflows using the CS-AF.

The research for this field study aimed to further validate the multifaceted and generalizable use of the CS-AF evaluation model for collaborative technology-mediated workflow in multiple domains. The research incorporated the three foundational elements of a technology-mediated workflow (infrastructure, interaction, and informatics) and established a framework and methodology, such that future iterations of the workflows can incorporate learning gleaned from the informatics collected during real-time operation of these technology-mediated workflows.

Problem Statement

This hypertension workflow incorporates a business-to-consumer (or in this usage, the doctor-to-patient) workflow for hypertension outpatients who need their blood pressure measured by a clinician (i.e., a current-state workflow.) Hypertension is a global and indiscriminate condition that effects on average over 25% of the adult population worldwide [178], [179]. One of the dilemmas associated with hypertension treatment is the obtaining of timely and accurate patient blood pressure readings. The current hypertension workflow requires patients to schedule and attend a visit to the doctor's office where the blood pressure reading is performed by a clinician. This current hypertension workflow process is not only time-consuming, but it is also riddled with a variety of issues that affect the very accuracy of the blood pressure readings; these include the time of day of the reading, "white-coat syndrome" (described below), patients' food consumption or hours of sleep, amongst other variables [180]. Related works and immersive analysis of both the patient and doctor's perspective of the current-state hypertension workflow identified a set of problems that will attempt to be addressed through this research.

From a doctor's perspective, there is no current way to view and analyze patient-introduced microdevice blood pressure data in the context of their standard practice and workflow. The only way doctors have of collecting patient blood pressure data is to see their patients in an office visit. This time-consuming blood pressure reading process becomes prohibitive when doctors desire close monitoring of hypertension patients on a more frequent basis. The current in-office blood pressure reading also introduces inconsistencies in the quality of the readings due to the white-coat syndrome and time-of-day fluctuations [181].

"White-coat hypertension" occurs with a subset of patients who are hypertensive according to their clinic blood pressures, but are normotensive (i.e., having normal blood pressure) at other times [178], [179]. The time-of-day fluctuations vary with patients, depending on their sleep, food intake, and other variables.

The American Heart Association suggests that the most accurate way to conduct a blood pressure reading is with the following protocol: Take two readings the first thing in the morning before food or medication within one minute of each other, then averaged. This is followed by two readings at the end of the day before bed and within one minute of each other, then averaged. The a.m. and p.m. averages are then averaged for the daily blood pressure reading [179], [182]. This suggested blood pressure reading protocol by the AHA would be impossible to conduct in an in-office setting.

With the refinement of blood pressure (BP) monitoring technology, patients are now able to conduct BP readings at home, then forward the data in batches for doctors to process. Pickering et al. state that "the potential advantages of having patients take their own blood pressure are twofold: the distortion produced by the white-coat effect is eliminated, and multiple readings can be taken over prolonged periods. Self-measurement of blood pressure at home has been shown to be useful in predicting target organ damage, cardiovascular events and mortality" [183:10]. Patient reading of BP data, while extremely valuable (i.e., timely and accurate) when compared to in-office BP data, is not well-integrated within the doctors' standard workflow, nor does it provide real-time visibility or opportunities for doctors to collaborate with patients. The current in-office approach enables a collaborative exchange between doctor and patient only when the doctor is brought into the discussion by the clinician conducting the blood pressure reading.

From the patient's perspective, there are many choices of consumer microdevices that offer heart rate and BP monitoring, all with varying degrees of accuracy. Patients want an easy-to-use approach for BP monitoring that is integrated into their smart-mobile device and, most importantly, is supported and integrated in their patient care with their doctor. Kalantari et al. state that, despite the hype about wearables, consumer adoption lags the smartphone rate of adoption; they have not gone mainstream because consumers have concerns about their accuracy and their typical non-integration into their patient care with their doctors [177].

Jacobs et al. posit that patients are interested in two collaborative drivers that may be facilitated through technology. Is the caregiver interested in the patient's condition, and is the caregiver equipped to provide a solution [184]? By using new technology to establish a more streamlined collaborative bridge between doctor and patients using the consistent evaluation approach of the CS-AF to collect the pre-post evaluation data, this research incorporates the patient's real doctor into this empirical study.

In discussion with the doctors involved in this study, they are most comfortable with the procedure and data that comes from the Omron BP Monitor, but not as confident with BP data coming from other wearables. Omron makes a consumer-oriented BP device that functions identically to the in-office unit used by the doctors involved this study. This Omron device was selected for this research since it supports the doctors' approach, and also since the device is portable and supports other important consumer features such as Bluetooth Wi-Fi connectivity.

This research aims to address the problems identified in the current-state workflow with the development of a technology-mediated collaborative workflow that integrates a cloud-based mobile app and FDA-approved Omron portable BP monitor. The mobile app and the microdevice have been integrated with a smartphone, allowing hypertension patients to conduct daily BP readings in the convenience of their home, under the observation of and in collaboration with their medical doctor.

5.2. CS-AF Methodology: Hypertension BP Exam Workflow

Exploration of the related works regarding collaborative workflow in the HIT domain yielded a variety of findings identified in the Related Works section and are highlighted herein [185]. Kuziemsky et al. explored a model of awareness that was intended to enhance understanding of collaborative care, delivery, and health information design. The research highlights aspects of awareness (similar to the Activity Awareness Model of Neale, Carroll, and Rosson) [13], [119], is focused on HIT and the hospital team doing their work, and presents four types of awareness: environmental, patient, team-member, and decision-maker [182]. This theoretical model was further explored by Eikey, Madhu, and Kuziemsky during a systematic review of 25 years of HIT research where the researchers conceptualized a more comprehensive framework to evaluate collaborative workflows in HIT [44]. Through their research, the authors conceptualized the Collaborative Space Model (CSM) as a summary construct that represents essential aspects of the HIT collaborative workflows that need to be evaluated in an integrated fashion. The CSM is illustrated in Fig. 33.

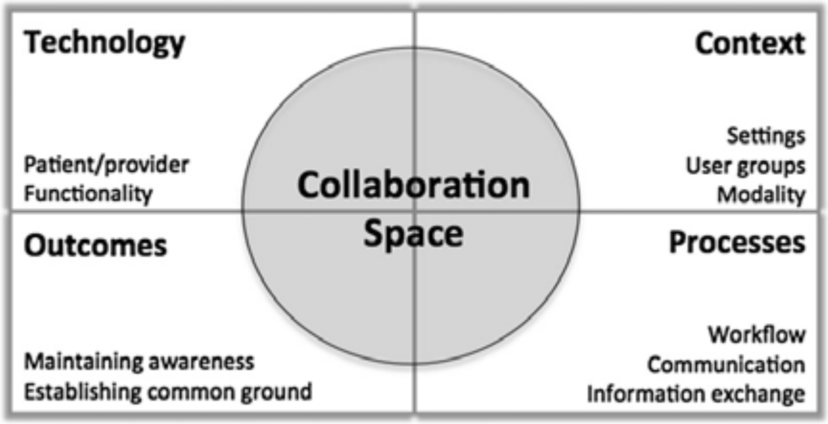


Figure 33: Eikey, Madhu & Kuziemsky's Collaborative Space Model

The CSM was constructed to visualize the collaborative evaluation requirements in the HIT domain as an outcome of the 25-year systematic study. As a theoretical model, the CSM identifies a set of high-level evaluation and comparison requirements that are intended to be fully addressed by use of the CS-AF. My phone sessions with the CSM researchers were conducted in an effort to make certain that the future research suggested by the CSM research team would be addressed using the CS-AF and further validated with empirical studies. The CS-AF and field research in the hypertension workflow was designed, amongst other objectives, in order to comprehend the requirements established in the CSM.

Jacobs et al. compared collaborative preferences of cancer patients, doctors, and navigators (i.e., hospital staff that provide procedural support for patients during the treatment process.) They suggest that "HIT has yet to provide features that allow providers to incorporate health information sharing preferences as a way to focus patient behaviors; there is a misalignment between patient, doctor, and the care-team. Such misalignments point to the need for future tools to help bridge the needs of healthcare providers with the behaviors of patients engaging in personal health tracking" [184:816].

The International Alliance of Patients' Organizations (IAPO) states that "patient-centered healthcare is designed and delivered to address the healthcare needs and preferences of patients so that healthcare is appropriate and cost-effective" [34]. The IAPO outlines five principles of patient-centered healthcare: "respect; choice and empowerment; patient involvement in health policy; access and support; information" [34]. Unless the collaborative processes between doctors and patients are streamlined, the ultimate goals of patient-centered healthcare established by the IAPO will not be attained. In order to design HIT systems that address the unique collaborative needs of both patients and doctors alike, both participants must be incorporated into the study in a live and real-world scenario.

Collaboration is the fulcrum point for enabling optimized workflow in HIT systems. A complete understanding of collaboration is essential in order to refine certain aspects of the workflow that affect a streamlined process. Weir et al. provide a functional definition of collaboration as "the planned or spontaneous engagements that take place between individuals or among teams of individuals, whether in-person or mediated by technology, where information is exchanged in some way (explicitly, i.e., verbally/written; or implicitly, i.e., through shared understanding of gestures, emotions, etc.), and often occur across different roles (i.e., physician and nurse) to deliver patient care" [40]. This research aims to evaluate the impact of technology-mediated improvements on the collaborative interactions of doctors and patients in a live example using the CS-AF as the structure.

The revised version of the CS-AF (shown in Fig. 34), which incorporates learnings from the GC empirical study, was used as the reference model and structured analysis methodology to evaluate the association between current-state and technology-mediated hypertension workflows. The CS-AF incorporates a structured framework and an analysis methodology to conduct a detailed collaborative workflow evaluation and comparison. The five elements of CS-AF are Context, Process, Technology, Behavior, and Outcomes. An integrated semi-structured, mixed-methods (qualitative and quantitative) survey instrument had been developed as part of the CS-AF. This specific survey instrument was incorporated at two intervals within this study: at the start, prior to any changes (current-state), and at the completion of the technology-mediated enhancement.

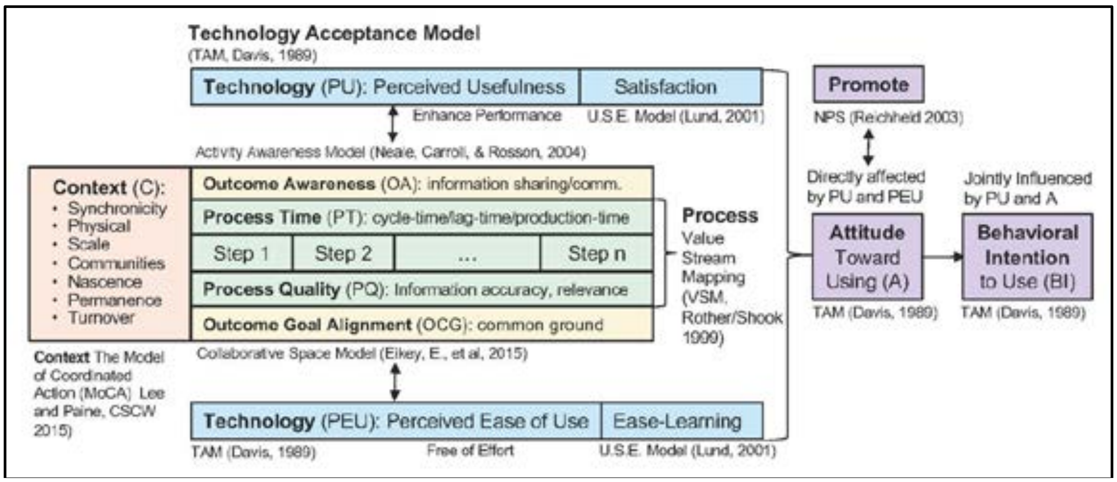


Figure 34: Bondy's Collaborative-Space Analysis Framework (CS-AF) V2

The final step in the CS-AF methodology is a comparison of the pre- and post-enhanced workflow analysis to determine how effectively the problems identified in the current-state workflow have been addressed.

The five sequential steps of the CS-AF methodology were followed in series by completing all the aspects of one step before moving on to the next step in the sequence. The five steps used in the CS-AF methodology for the doctor-patient hypertension collaborative workflow (discussed in detail in Chapter 4) were:

1. Current-State Workflow Definition - CS-AF Survey Refinement
2. CS-AF User Survey - Current-state (Baseline) Blood Pressure Exam Workflow Data Collection (Phase 1: Field Trial)

3. Technology-Mediated Enhancement – Development, Field Usability Test, and Deployment (Phase 2: Field Trial)
4. CS-AF User Survey - Technology-Mediated Workflow and Manual Workflow Data Collection (Phase 3: Field Trial)
5. CS-AF Collaborative Workflow Analysis – Evaluation between Baseline Current-State and Manual and Technology-Mediated Blood Pressure Exam Workflow (Phase 4: Field Trial)

CS-AF Survey Design

The CS-AF survey instrument is an integrated set of qualitative statements that are ranked by test participants' using a 7-point Likert scale (ranging from 1-Extremely Easy through 7-Extremely Difficult) for 5 major areas of investigation (Context, Process, Technology, Attitudes & Behaviors, and Outcomes), incorporating single-response statements.

This research included electronic (online) administration of the CS-AF survey in a semi-structured and interactive fashion in efforts to minimize the variability that can arise with self-reporting. Each section of the CS-AF survey was introduced to set the context of the section, followed by each specific question in a live video conference setting. The aim for this approach, although more time-consuming, was to capture as consistent and accurate information as possible from each respondent.

Each test participant completed an initial pre-test CS-AF survey (blood pressure exam baseline), then was randomly assigned into one of two groups (Group 1: Manual BP Exam Workflow or Group 2: Technology-Mediated BP Exam Workflow). Test participants proceeded with a minimum 3-week clinical trial using the test protocol specific to each group. Following the 3-week trial test period, all test participants completed a second CS-AF survey with identical questions as the pre-test CS-AF (blood pressure exam baseline) survey pertaining to the 3-week trial.

All test participants were evaluated following a current-state blood pressure exam workflow as a baseline using the CS-AF survey instrument (referred to as CS-AF - Test A). Test participants were then randomly assigned into two test groups (based on age and gender); test Group 1 were test participants received a manual blood pressure exam workflow, and test Group 2 test participants received the technology-mediated blood pressure exam workflow.

Sample Size and Participants

The sample-size determination for the two-sample, paired *t*-test is estimated by the following process, resulting in a sample-size of approximately 25 pairs.

- Type I error rate alpha = 0.05 (default value in most studies)
- The least power of the test wanted to achieve (=70%)
- Effect size (here, for example, = 0.5, for a pilot study to estimate this effect size)
- Standard deviation of the change in the outcome (for example, = 1; a pilot study can be used to estimate this parameter).

Age Range	Average Systolic	Systolic Range	Average Diastolic	Diastolic Range
18-24	120	105-132	78	73-81
25-34	121	109-134	80	76-85
35-44	124	111-137	82	78-87
45-54	128	115-142	84	80-89
55-59	131	118-144	86	82-90
+60	134	121-147	87	83-91

Table 13: Hypertension age bands

The participants in this hypertension field study were 50 hypertension/pre-hypertension patients that were selected in cooperation with a local medical doctor.

As outlined in Table 13, *The Archives of Internal Medicine* and the American Medical Association have identified hypertensive age bands that were followed for this research [178], [179], [186]. In order to conduct a matched-pair *t*-test based on age and gender, 25 pairs of male and female patients were needed. A minimum of four male and four female hypertension patients from each of the six age bands were selected for this study; there was a minimum of 25 pairs or 50 patient-participants. Within each pair, subjects were randomly assigned to two groups (Test Group 1: manual BP workflow and Test Group 2: technology-mediated BP workflow) with the following example distribution:

Matched Pairs 1-25	Test Group 1: Manual BP WF	Test Group 2: Tech-Mediated BP WF
1-M 18-24	x	x
2-F 18-24	x	x
3-M 25-34	x	x
4-F 25-34	x	x
…		
n	x	x

Following initial training on the technology-mediated workflow (BP monitor device and mobile application), test participants conducted daily BP readings for a minimum three-week period, following a specific procedure (described in the section below).

Based on the data, a paired test could be performed to evaluate the response values between the baseline workflow of two groups and their respective workflow, manual vs. technology-mediated. The hypothesis examined the difference of the observation means between two groups. If the assumption of a normal distribution of the differences was unjustified, a non-parametric paired two-sample test (the Wilcoxon matched-pairs signed-ranks test) would be performed. If there was a normal distribution assumption, a two-sample paired *t*-test would be performed.

Test Duration

Following the initial data collection for the current-state BP exam workflow using the CS-AF survey instrument and training on the manual or technology-mediated workflows, respectively, test participants conducted twice-daily BP readings (two readings per interval) for a three-week period following a consistent BP measurement procedure. The three-week test period duration was followed to adequately accommodate a complete technology adoption-cycle (introduction, highly-motivated use, through acceptance, and tailing-off of use) [187].

Since the primary focus for this research was the evaluation metrics and analysis of collaborative technology-mediated workflow, and not the clinical analysis of blood pressure improvement over time, the field test time duration determined for this research was based on accommodation of ample time for test participants to learn the new workflow and to transfer the newness of the experience into a habitual process that they could perform routinely. This research was focused on the evaluation of technology-mediated adoption in collaborative workflows and, therefore, once the initial "hype" of newness has worn off and the workflow was then routine, the post-technology survey data would reflect the perspectives of the test participants regarding the routine and habitual use of the technology-mediated workflow, compared with the current-state workflow, which had also become routine [188], [189], [190].

This field study involved two blood pressure reads–twice daily–and therefore produced two test intervals per day, as compared to traditional blood pressure trials that deliver approximately three test intervals per week. Over the course of a traditional 12-week trial period with three test intervals per week, a traditional blood pressure trial would deliver 26 test intervals. This research delivered 42 test intervals over a 3-week period, due to the ease of use and frequency of blood pressure exams using the smartphone app developed for this research. [191], [192], [193].

A test duration of three weeks is ample time for habituation to form with the usage of this simple smartphone app, used to conduct the exact same BP test twice a day. Tele-medicine assessment guidelines indicate that the filed assessment period is a variable that should be determined by the complexity of the application. Research for related tele-medical smartphone applications range from field assessment durations that are single-day, single-session evaluations, to evaluations over 30 days, although typically not over multiple months unless the evaluation is associated with a clinical trial [194], [195].

Ethics, Privacy, and Confidentiality of Test Participation

Test participants were selected from a pool of hypertension patients provided by the private practice of Dr. Pam Grover, MD, in Rochester, NY. Each participant was presented with an Informed Consent that described the detailed objectives, research process, and participant requirements for this study. In addition, each participant was asked to acknowledge agreement with the terms and conditions of this research. The following paragraph is an excerpt of this Informed Consent document:

> The objective of this study is to evaluate a comparison between the current process for a blood pressure exam compared with a "new" technology-mediate approach using the remote BP device and the smartphone app. A second goal of the study is to validate the general use of the unique survey comparison methodology that has been developed for this study. The semi-structured interview will follow a consistent set of structured and unstructured (open-ended) questions that are organized in the following categories in the table below. [Informed Consent: Appendix B]

The information obtained in this research will be treated as private and confidential, and protected from unauthorized disclosure, tampering, or damage. All information collected through the semi-structured interviews was transferred to a database/spreadsheet, and the original collection material will be destroyed. The participant entries were coded as participant numbers, such that no personal references were made on any material or data files. The keycode for the participants was stored in a separate data file that was encrypted and password-protected. All survey data was also encrypted and password-protected. The summary data generated from the analysis of the semi-structured interview was anonymized by a classification of Male/Female, Age, and with/without the technology; there will never be any correlated data that maps back to the individual study participants by name at any level throughout this study.

Researchers in the health and medical arena strive to find the best ethical scenario for test participants to provide valuable information, while delivering safe and meaningful utility for their time spent and ongoing health concerns [196]. Specifically, research must take care to deliver health and wellness solutions that provide value to test subjects during the evaluation period and beyond. Mittelstadt posits that there should be as transfer of technology that improves the health and well-being of the patient and overall quality of the healthcare service as a result of any proposed technological advancement involving live patient test subjects [197]. With this ethical goal in mind, this research provided a blood pressure measuring system (device, instruction, software) for each test participant to use during the three-week trial, as well as to keep for their personal use beyond the trial period for this research.

Field Trial Procedure

The test sequence for this research was structured into four sequential phases, as described below.

Field Trial Phase 1: The first phase of the field study included a baseline evaluation of all 50 test participants using the CS-AF survey instrument for the current-state "in-doctor's office" blood pressure workflow; this is referred to as Test A.

Pre-Test: Traditional "doctor's-office" BP Exam Workflow Survey**.**

All participants were baselined for the current-state blood pressure exam workflow using the CS-AF survey instrument.

Participants	Test Description	Measure/Analysis
All Test Participants	Current-State Baseline BP Exam Workflow	CS-AF Survey Instrument

Field Trial Phase 2: For the second phase of the field study, both Group 1 and Group 2 proceeded with conducting daily blood pressure readings for a minimum of three weeks, adhering to the instructions associated with each specific group.

All test participants were then randomly assigned into two groups:

- **Group 1: Manual blood pressure exam workflow (control group)**
- **Group 2: Technology-mediated blood pressure exam workflow**

Field Trial Phase 3: The third phase of the field study involved all test participants in both Group 1 and Group 2 conducting a second CS-AF evaluation survey, using the same CS-AF survey instrument as was used for Test A. This specific evaluation was called Test B for Group 1 and Test C for Group 2.

Post-Test: Manual BP Exam Workflow Survey.

Group 1 participants were evaluated following the three-week minimum blood pressure field test using the manual (i.e., wrist-cuff) workflow.

Participants	Test Description	Measure/Analysis
Group 1	(3 weeks) Technology-mediated BP workflow	CS-AF Survey Instrument

Post-Test: Technology-Mediated BP Exam Workflow Survey.

Group 2 participants were evaluated following the three-week minimum blood pressure field test using the technology-mediated workflow.

Participants	Test Description	Measure/Analysis
Group 2	(3 weeks) manual BP workflow	CS-AF Survey Instrument

Field Trial Phase 4: The fourth and final phase of the field study incorporated a systematic analysis of the survey data recorded from Tests A, B, and C, including a comparison amongst the three groups across for each of the determinants in the CF-AF.

Group 1 Analysis: comparative analysis between Test A (current baseline blood pressure exam workflow) and Test B (manual wrist-cuff blood pressure exam workflow)

Participants	Test Description	Measure/Analysis
Group 1	Comparison between current-state WF (Test A) and manual wrist-cuff WF (Test B)	CS-AF Survey Instrument

Group 2 Analysis: comparative analysis between Test A (current baseline blood pressure workflow) and Test C (technology-mediated blood pressure workflow)

Participants	Test Description	Measure/Analysis
Group 2	Comparison between current-state baseline WF (Test A) and technology-mediated WF (Test C)	CS-AF Survey Instrument

Group 1 versus Group 2 Comparison: comparative analysis between Test B (manual blood pressure workflow) and Test C (technology-mediated blood pressure workflow)

Participants	Test Description	Measure/Analysis
Group 1 and Group 2	Comparison between (Test B) Manual wrist-cuff WF Technology-mediated WF (Test C)	CS-AF Survey Instrument

Analysis D: Cross-determinate analysis of select CS-AF determinates from Group 1 and Group 2, and comparison with the baseline current-state (in-office) blood pressure exam workflow.

Participants	Test Description	Measure/Analysis
Group 1 & 2	Select cross-determinant analysis between participants in all three groups	CS-AF Survey Instrument

The following cross-determinate elements of the CS-AF were analyzed:

- Ease of Use, Ease of Learning, Perceived Usefulness, and User Satisfaction (Lund, Model)

CS-AF Statistical Basis and Analysis Procedure

The CS-AF survey data was collected for both the pre- and post- workflow trials for Group 1 and Group, and the following five-step analysis was conducted using the survey data. (The processes and procedures for each step in this analysis are described in detail in Chapter 3.2.2. and are illustrated in Fig. 35)

1. **Data Processing**
2. **Test for Normal Distribution**

3. **Repeat measures ANOVA:**

4. **Analysis of Means**

5. **Matched-Pairs *t*-Test**

5.3. Current-State (baseline) Hypertension - Blood Pressure Exam Workflow

The current-state BP workflow step in the CS-AF methodology involved an initial unobstructed observation and recording of the target workflow in a natural setting, followed by a distillation of the observed current-state (in-doctors-office) blood pressure exam workflow into a logical set of sequential workflow steps that represent the hypertension measurement workflow as it currently exists. This process was then used to refine the specific workflow steps that were to be used in the CS-AF survey instrument.

For the current-state in-office hypertension workflow, the completed preliminary field work involved shadowing and recording the specific sequential steps as a silent observer. Care was taken for this preliminary analysis to observe the natural setting and hypertension reading process in an obstructed manner with no interactions with the administrative staff, patient, nor clinician.

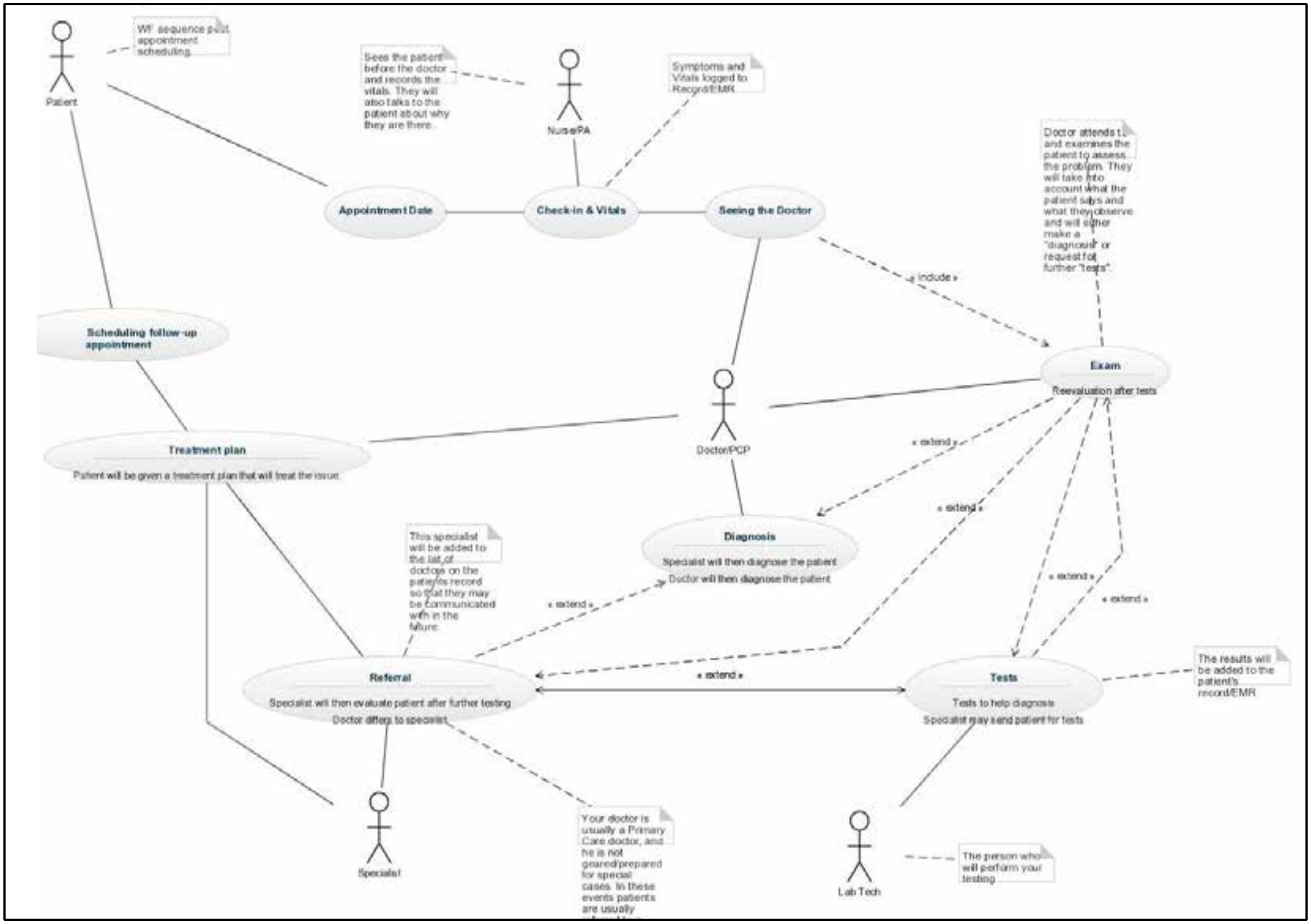


Figure 35: Use Case Model, Current-State Hypertension Workflow

In order to further visualize and explore the hypertension workflow in the natural practitioner in-office setting, a detailed use case model was developed from this initial workflow observation (and is illustrated in Fig. 35) This hypertension workflow use case was then analyzed to create the specific current-state hypertension workflow steps that were to be used in the CS-AF.

The discrete workflow steps identified for the hypertension measurement workflow were defined as a result of the initial field analysis and were reviewed for completeness with the two doctors participating in this study.

This current-state hypertension measurement workflow process established for this empirical study followed these steps:

1. **Pre-Visit:** Patient or Doctor determines the need for an in-office blood pressure reading and schedules the appointment with the administrative staff.
2. **Registration:** For the scheduled appointment, the patient arrives at the doctor's office and checks in at the registration desk. Following check-in, the patient waits for a clinician to conduct the blood pressure exam. Fig. 37 shows the initial check-in location and paperwork.

Figure 37: Registration and check-in process

3. **Exam:** The clinician or doctor leads the patient to the examination room and conducts the blood pressure exam (as shown in Fig. 38) Upon completion of the blood pressure exam, the clinician advises the doctor that the exam is complete.

Figure 38: Blood Pressure Exam

4. **Treatment:** The doctor enters the examination room, greats the patient, reviews the blood pressure exam results, and discusses the results and possible follow-up treatment plan with the patient.
5. **Post-Visit:** The doctor updates the patient's electronic health record, and patient checks out with the administrative staff, leaves the office, and completes any follow-up treatment prescribed by the doctor (self-treatment; follow-up visits with the doctor, lab, or specialists.) Fig. 39 shows some of the checking-out processes, including the eRecord interface.

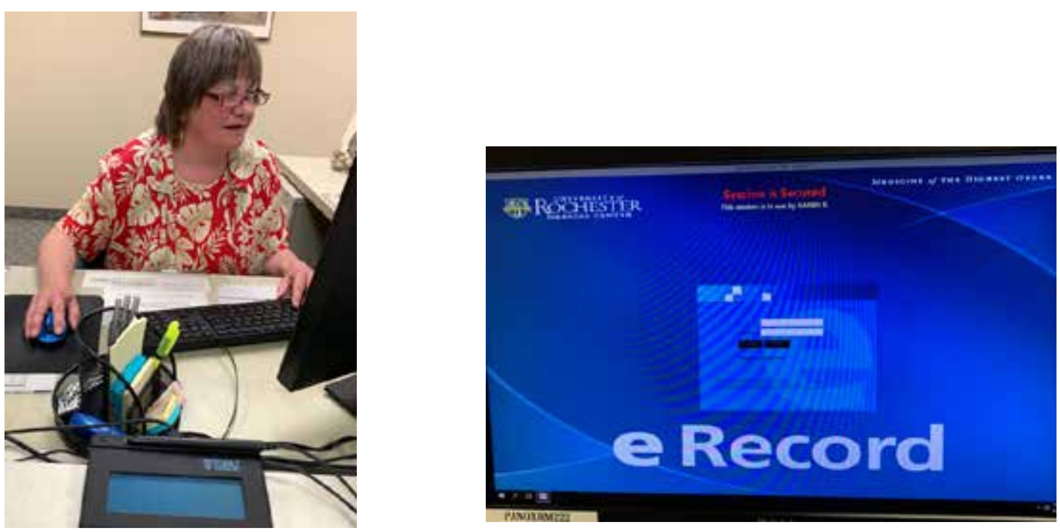


Figure 39: Blood Pressure Recording and Check-Out

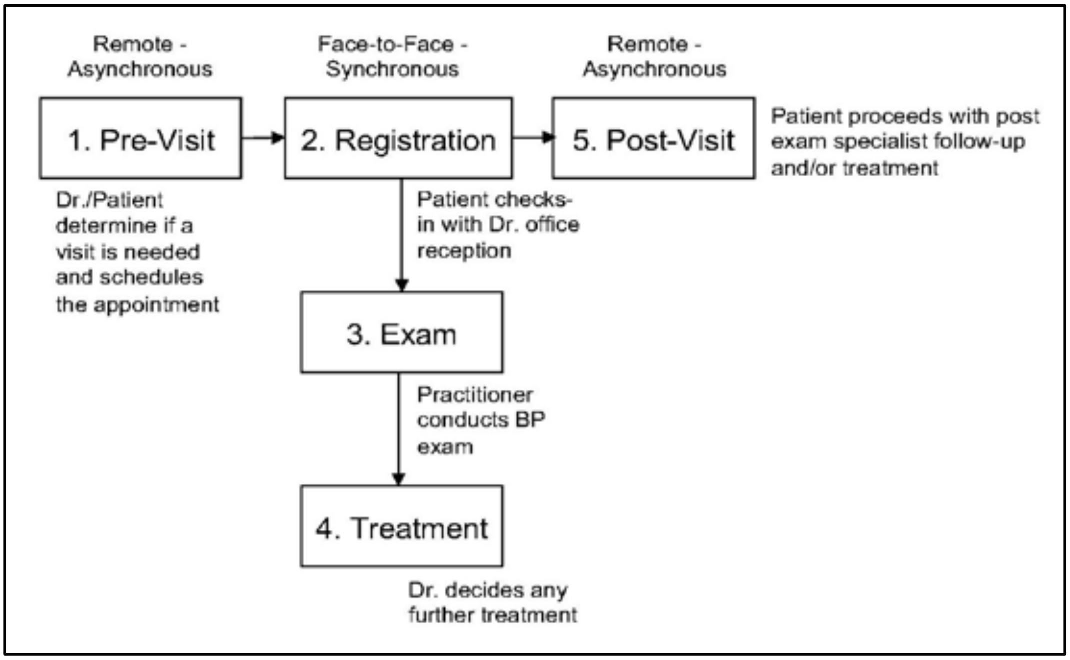


Figure 40: Bondy’s current-state hypertension workflow

The five hypertension measurement workflow steps defined in this initial field analysis (Pre-Visit, Registration, Exam, Treatment, and Post-Visit) were then used to refine the CS-AF survey instrument. In this way, each of the five sequential workflow steps were integrated into the survey, and the targeted collaborative workflows analysis could be based on these foundational workflow steps. Fig. 40 outlines the current-state hypertension workflow.

The aim for research was to conduct a baseline current-state analysis of 50 hypertension test participants, based on age bands and gender using the CS-AF survey instrument, followed by a random selection of one participant from each pair to processed with the technology-mediated workflow. The field engagement was completed via a second survey of all participants. This would enable a thorough evaluation, comparison, and analysis of the current-state workflow, compared to the technology-mediated collaborative workflow using the CS-AF.

5.4. Manual Hypertension Blood Pressure Exam Workflow

The "manual" hypertension blood pressure exam workflow was used to establish the control group for the field trial (Group 1.) Patients enrolled into the manual BP workflow group received a personal wrist-type blood pressure monitor device, along with instructions and a daily blood pressure log form to manually record daily blood pressure readings.

Test participants enrolled into the manual BP exam workflow followed a daily blood pressure exam workflow similar to what was described previously for the technology-mediated workflow, with the main difference being that all blood pressure readings performed on the wrist blood pressure monitor were recorded manually on the blood pressure log form that was provided to each test participant. Test participants conducted two a.m. blood pressure readings, then took those the values and divided them by two, and then wrote that a.m. average on the form; those participants completed the exact same procedure for the two p.m. blood pressure readings.

Manual BP test participants (Group 1) received an online video training session, accompanied by a printed instructional manual that describes the daily procedure to be followed for the manual BP workflow process. The exact same information regarding the blood pressure reading position and process previously discussed for the technology-mediated workflow were communicated to the manual BP test participants.

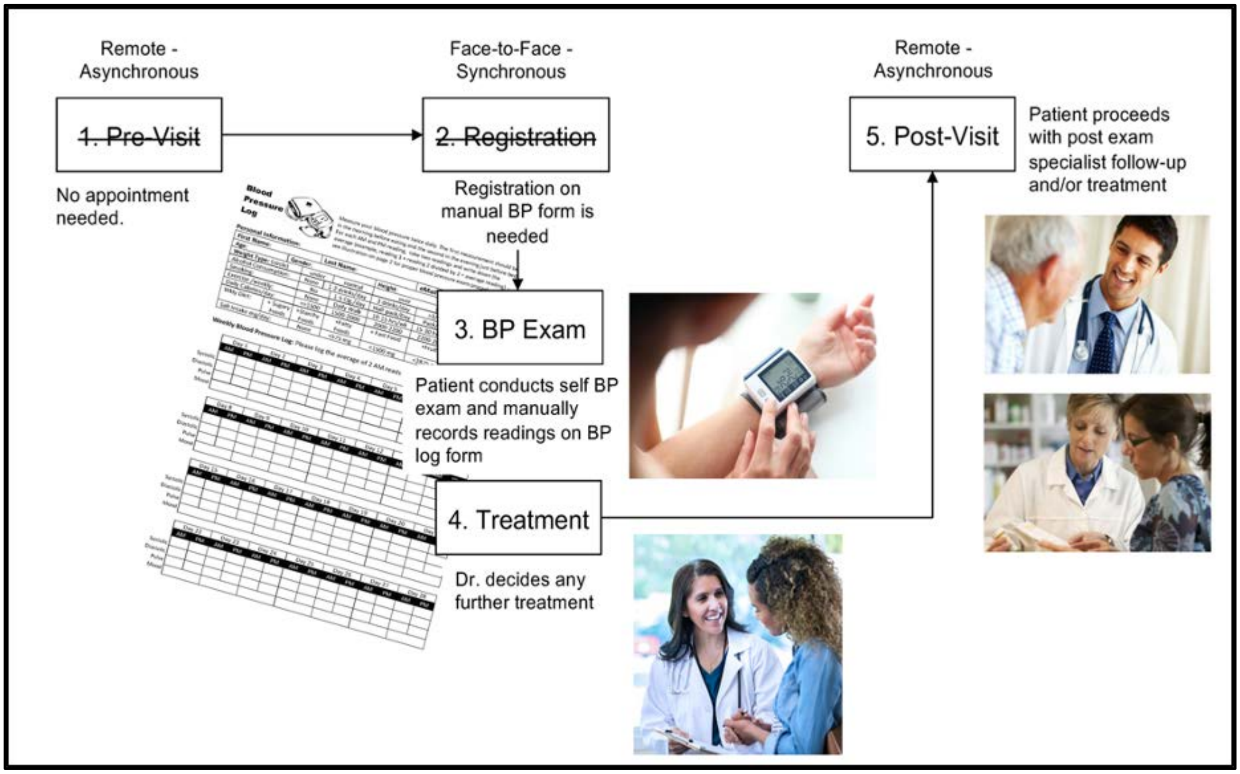


Figure 41: Bondy's Manual Hypertension Workflow (Group 1)

5.5. Technology-Mediated Blood Pressure Exam Workflow

The technology-mediated hypertension workflow development goals are to enable a more streamlined and collaborative workflow that addresses both the needs of the doctor and those of the patient together in an integrated experience. The current in-office BP measurement process for hypertension requires patients to schedule and make a visit to the doctor's office where the BP reading is performed by a clinician. This current hypertension workflow process is not only time-consuming, but it is also riddled with a variety of issues that affect the very accuracy of the readings (e.g., time of day, "white-coat syndrome," food consumption, hours of sleep, amongst other variables) [Rothwell]. This current-state workflow is inefficient and non-collaborative, and does not enable accurate and timely BP monitoring.

The design goals for doctors include:

- Accurate patient blood pressure readings
- An automated flow of each patient's discrete BP data that can be viewed from the doctor's smartphone
- Automated BP thresholds based on target BP values associated with each patient
- Automated and custom alerts and messaging to aid in doctor-patient collaboration
- An automated wellness feed to patients with doctor-vetted proactive wellness information that matches each patient's specific health profile
- The ability to receive patients' messages
- The ability to search and review individual patients and patients' groups based on custom profile searches

The design goals for patients include:

- A convenient, easy-to-use, safe, reliable, and accurate BP monitor device that is integrated with a patient's Apple or Android smartphone and can be used in the privacy of the patient's own home
- Accurate daily BP reads that are automatically collected at two intervals and are averaged for the day
- An automated processing of BP data directly to the patient's doctor
- Automated system alters notifying patients of BP readings that are out of range
- Direct collaborative communication with the doctor via messaging services in the BP app
- Encouraging proactive wellness information that is provided by their doctor

The technology-mediated collaborative workflow for hypertension patients needing to monitor their blood pressure is a more streamlined process than is the current-state workflow. The use of technology introduced in this research (a personal Omron BP monitor device and the Wise & Well blood pressure monitor that is integrated with the patient's doctor) is reflected in the technology-mediated workflow to follow, as shown in Fig. 42.

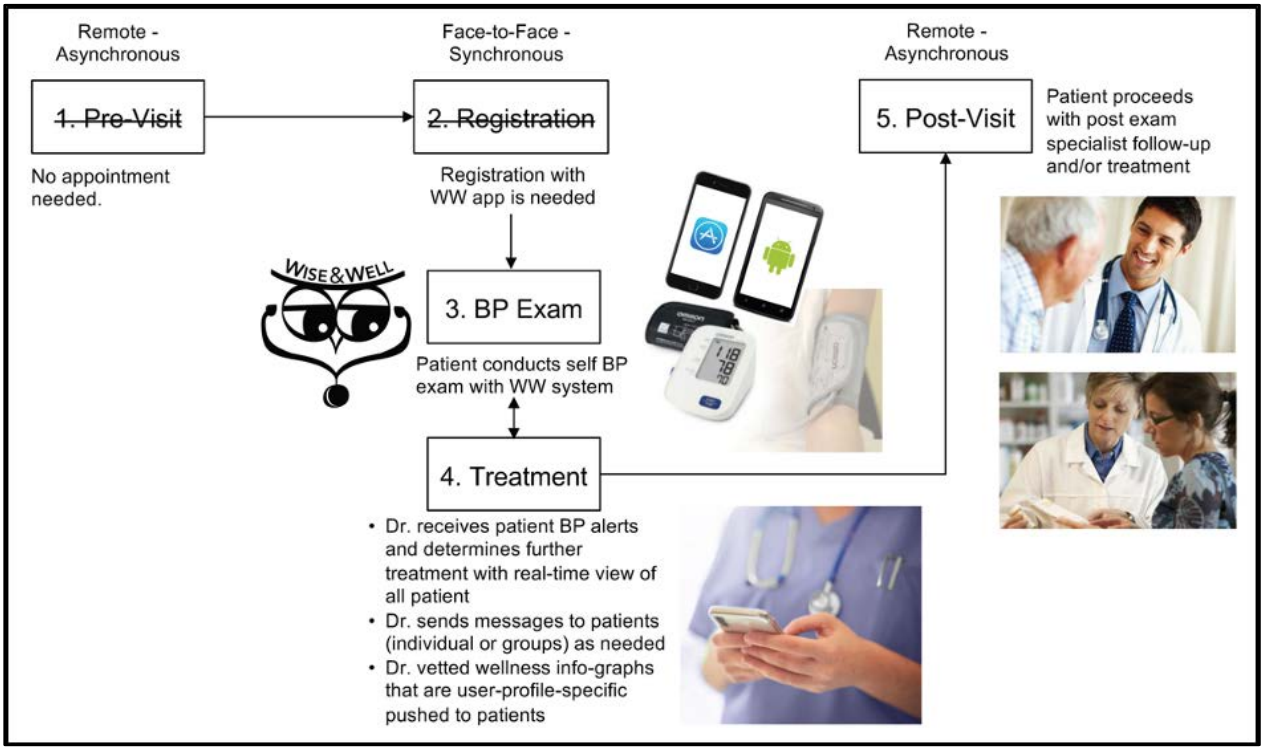


Figure 42: Bondy's Technology-Mediated Hypertension Workflow (Group 1)

The Wise & Well Blood Pressure Monitor (WW-BPM) was designed to facilitate the timely and accurate BP reading, and the communication of the patient BP data in a real-time nature to the patient's doctor in a collaborative application that enables doctor-patient interaction.

Initial development, using Withling's personal BP personal device integrated into the Wise & Well app via the OpenMHealth API (application programming interface), was completed and tested. This implementation was, however, somewhat cumbersome and slow, requiring patients to secure a Wi-Fi connection to use the Web-based app that functioned with the OpenMHealth API.

It was determined that this initial Withlings BPM was not a viable approach, so it was re-designed to work as a comprehensive mobile app with a Bluetooth connection to the monitor, with a batch transfer of BP data when the smartphone has a Wi-Fi connection. This revised design approach enabled a more streamlined operation for the patient that does not require a Wi-Fi connection. The Omron HEM-9200T BP monitor was selected for this application development over the Withlings device, since it was most favored by the doctors and was designed with a Bluetooth API that facilitated the successful development with the mobile applications.

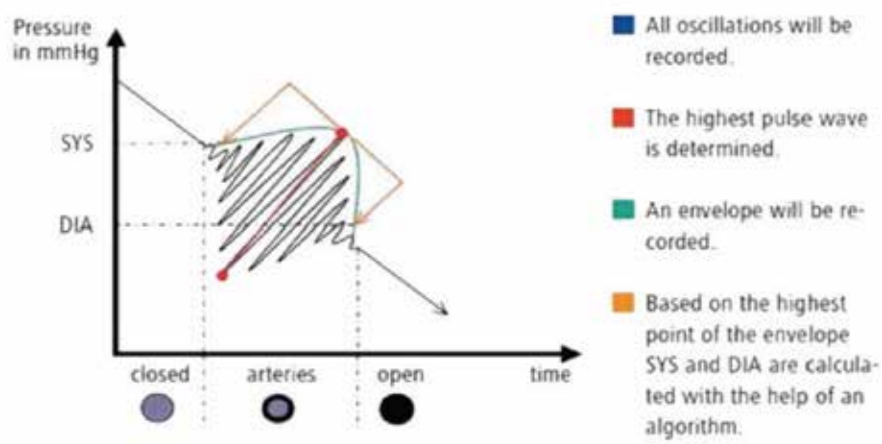
This integrated technology-mediated system, the WW-BPM, delivered an integrated, secure, and easy-to-use workflow solution for blood pressure reading and monitoring of patients with the hypertension condition. The final design of the WW-BPM includes an Apple iOS and Android application that test participants would use, in concert with the Omron HEM-9200T BP monitor, that was also provided at no cost to the test participants. Fig. 43 shows the Omron 9700T monitor.

Figure 43: Omron 9700T Personal Blood Pressure Monitor

The Omron 9700T Personal Blood Pressure Monitor offers these capabilities:

- Oscillometric Cuff Method
- Serialized by user

- Provides date, heart rate, systolic, diastolic data
- FDA-cleared device
- Available on iOS and Android
- Bluetooth or Internet connectivity
- Integrated with the Wise & Well smartphone app for iOS and Android

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        }
    }
```


Figure 44: Blood Pressure Data from Omron device

The Omron BP Monitor delivers oscillometric BP data to the WW-BP app; each reading displays a systolic, diastolic, heart rate, and date/time data. The WW-BPM receives the data via a Bluetooth connection and calculates the daily average BP reading for the patient and doctor to observe.

The WW-BPM user interface allows users to monitor the statistics of their blood pressure readings. In order to provide a more accurate representation of the patient's true BP, the readings are averaged daily. The application also delivers this BP data and notices to the doctors when patients' BP readings are elevated beyond an acceptable range.

Patients also received wellness data based on their specific health profile, associated with hypertension accelerators such as smoking, salt intake, diet, exercise, weight, and alcohol consumption. In order to facilitate future informatics portraying the functional use of the system, the application incorporated a database of transactions that can be further monitored and analyzed. Fig. 45 illustrates the system.

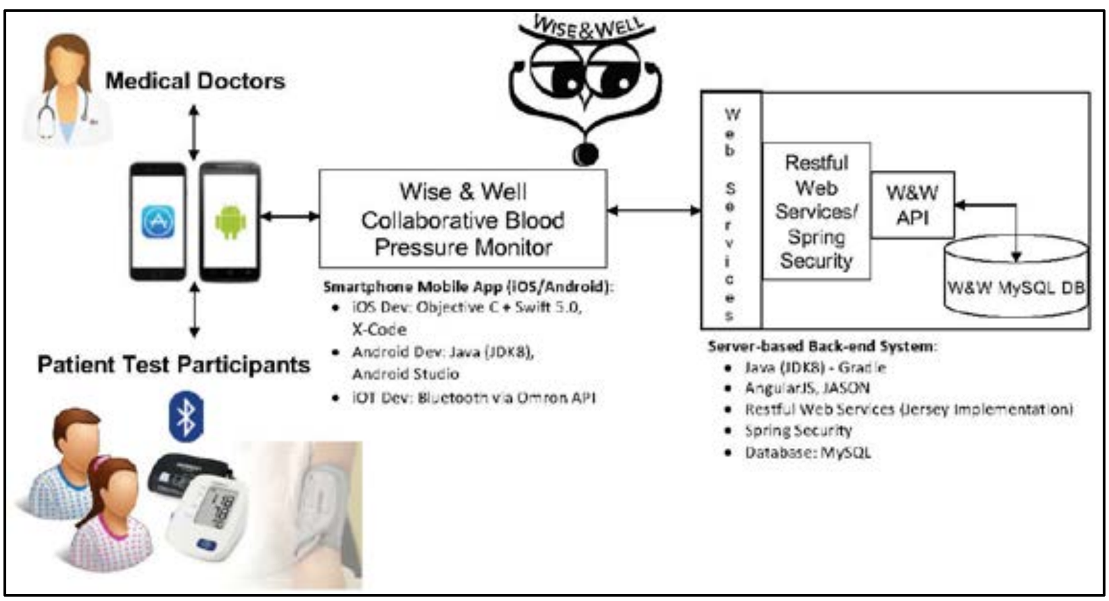


Figure 45: Bondy's Technology-Mediated – Wise & Well Blood Pressure Monitor System

Participants in this study received the Omron HEM-9200T blood pressure monitor and training on the WW-BPM prior to beginning the official two-week test period.

The specific blood pressure monitoring procedure to be followed by participants involved in the technology-mediated collaborative workflow is described below.

Following training and orientation on the WW-BPM system (Omron device and mobile application), each test participant would adhere to the following daily BP procedure:

1. **Pre-Visit** (face-to-face and remote – synchronous):
   Patient receives training on the WW-BPM and Omron device, downloads the WW-BPM application, and receives the Omron HEM-9200T BP monitor. The patient registers as a user on the WW-BPM and defines their specific profile for the following hypertension triggers established by the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: Age, Gender, Weight, Salt Intake, Exercise, Alcohol, Smoking, and Diet [186].
2. **Registration:** This step is no longer required in a face-to-face setting; registration on the Wise&Well and is required with the technology-mediated workflow.
3. **Exam** (remote – asynchronous)

Patient captures twice-daily blood pressure readings with the WW-BPM system per the following blood pressure reading and patient positioning procedures (as illustrated in Fig. 46 from the American Heart Association):

Blood Pressure Reading Procedure:

- Start the WW-BPM app on your smartphone
- Ensure that the Omron device is attached to your smartphone via Bluetooth and that it is running.
- Secure the blood pressure cuff to your bicep per the standard blood pressure position described below.
- Initiate the BP reading.

Blood Pressure Standard Patient Positioning:

- Do not smoke, exercise, or drink caffeine or alcohol for 30 minutes prior to your

BP reading time.

- Sit in a chair for 5 minutes. Ensure that your left arm is supported (i.e., resting on a flat surface at heart level.) Sit calmly and do not talk.
- Place the cuff on your left arm. Position the bottom of the cuff just above your elbow.
- Take two BP readings (less than 1 minute apart) at two intervals each day, for a total of four BP reads.
- Two reads at two times a day (AM and PM)
- AM Reads – before any medications (Read 1, then less than a minute later, Read 2)
- PM Reads – before dinner (Read 1, then less than a minute later, Read 2)

Figure 46: The AHA's at-home blood pressure procedure

Patient continues to conduct daily BP readings using the WW-BPM application, and daily average blood pressure readings are sent to the doctor. The doctor monitors along any BP reading that falls outside the specific acceptable hypertension range that has been established for each patient. Doctor remotely evaluates the various BP data for patients and determines if an on-site appointment is necessary. If the BP is within the acceptable range, the "no appointment necessary" WW-BPM system-generated response is sent to the patient; the doctor always has the option of generating a custom message to any patient or group of patients. For BP readings that are out of range, a series of messages are delivered to the patient, depending on the severity of the reading.

If the doctor determines that an on-site appointment is required, the doctor's office contacts the patient for an appointment, or a message is sent via in the WW-BPM app requesting that the patient make an appointment.

4. **Treatment** (both synchronous and asynchronous):

   Patients continue with multiple daily BP readings and view the average BP rates in the WW-BPM app.

   Patients receive personalized wellness information through the WW-BPM application, based on their specific personal profile indicating any of the six possible blood pressure accelerators that the patient might have (smoking, alcohol, weight, exercise, salt, or diet).

   Patients have the ability to interact with their doctor privately.

5. **Post-Visit:** Post-visit actions are directed by the doctor to the patient.

   As long as each patient complies with conducting daily BP readings and these readings fall within the acceptable hypertension thresholds, the patient will continue to function remotely until the doctor determines an on-site appointment is required. The doctor has the ability at any time to collaborate with the patient and request other follow-up procedure as needed.

5.6. CS-AF Blood Pressure Exam Workflow Usability Test

5.6.1 Usability Test

Prior to conducting the blood pressure field trial, a comprehensive usability test was conducted to validate the functional use of the technology-mediated solution with respect to the target participant users. Since the manual wrist-cuff used for Group 1 (manual workflow group) incorporated existing technology and manual logging of BP readings, there was no usability test for this system; however, complete documentation, a training video, and one-to-one support was provided to both groups during the actual field trial. For this usability test, a minimum of one user was selected for each of the six age-bands represented in this study. The participants involved in this usability test adhered to and followed the test procedures, and were then disqualified from the subsequent field trial.

The usability test was designed to elicit feedback from participants that resemble identical profiles of the target users intended for the blood pressure exam field trial. Four use-cases were included in this usability test, and a consistent set of usability metrics were evaluated through an online survey that each usability test participant completed conducted at the conclusion of the usability four-day minimum test period.

The objective of this usability test was to evaluate the user acceptability across three areas of usability, (1) Ease-of-Use, (2) User-Friendliness, and (3) Functional Acceptability, as they pertain to four specific use cases that were intended for the blood pressure exam workflow field study. The scope of the usability study is the intended technology-mediated workflow that will be used for the collaborative blood pressure exam workflow study incorporating the Omron blood pressure device and the Wise&Well smartphone application (the "system"). The objectives for each area of the usability test and use-case scenarios are summarized below.

5.6.2 Usability Test – Survey Results and Analysis

The Usability Test survey is included in Appendix C. The test included a range of usability survey questions that were rated using a 7-point Likert-scale, as well as open-ended subjective questions. A summary of the data collection and analysis follows.

Demographics: The Usability Survey incorporated a variety of target users with a minimum of 1 user per each of the 6 age-bands that are intended for the field test and discussed previously. Other relevant demographic data from the Usability Test participants is listed below:

Total Usability Test Participants: 8

Male vs. Female test participants: 2 - Male, 4 - Female

Smartphone (iPhone vs. Android): 7 - iPhone, 1 – Android

Each of the usability factors listed above was evaluated in the context of Use Cases 1-4, described below. Usability test participants were provided with a test packet which included the identical items planned for the blood pressure field trial, including printed and online user documentation and the Omron bicep-cuff blood pressure monitor. The documentation describes and illustrates the Wise&Well (W&W) app download and install procedure, app set up (app registration and device-pairing procedure), and the twice-daily blood pressure exam procedure.

The Usability Test survey included Likert-scale survey questions in the areas of ease-of-use, user friendliness, and overall functionality per the four use cases described below. In addition, open-ended subjective questions were included to allow for more individual commentary on the usability and issues associated with the system.

Use Case 1: Download and Installation of W&W Application

Usability Test users were directed to Google Play (Android) and Apple TestFlight (iOS) respectively to download and install the W&W app on their smartphone. (Note: the Omron HEM-9200T BP device has been validated by Omron Corporation as a fully tested, AHA- approved commercial BP device, and was validated by Dr. Grover for this research study.)

Users experienced some difficulty with the download and install of the W&W app, largely due to the unique distribution method dictated by both Apple and Google for the distribution of Beta software. Apple uses the "TestFlight" platform, and Google uses "Google Play" to enable select users to have access to pre-release Beta software. None of the usability test participants had prior experience with Beta release software; this unfamiliarity caused confusion, evidenced by 50% of the users expressing that they had some difficulty during the installation process. Test participants expressed that field trial users and " … some participants will need help downloading the app". Since the Beta release software process is dictated by both Apple and Google, the remedy for this issue is to provide online video training for all participants, as well as access to the W&W website with more elaborate documentation.

Use Case 2: Wise&Well Application Setup and Registration

Upon completion of the W&W app install, all usability testers were instructed to register on the W&W app, to pair their Omron BP device using the Bluetooth service, and to conduct an initial test BP reading.

Six out of eight users (75%) experienced some difficulty with the W&W app registration and the pairing of the Omron BP device using Bluetooth. This was by far the largest area of concern uncovered during the usability test for the system. The W&W user registration process requires the creation of a user account (using the user's email and password,) followed by the creation of a user profile. The process is somewhat rigid in that the user account must be created prior to creating the user profile, and for the W&W app to function correctly, both procedures need to be completed. Users expressed that the procedure was too structured, and error-recovery was not very robust, and that, "less techy participants will need one-on-one support during the initial app registration." Further analysis of the W&W app registration process did uncover a system error that occurred when a user deviated from the set registration procedure; that error was then resolved. More elaborate documentation with step-by-step procedures, including screen shots, have been developed to support future users.

Usability test users also expressed difficulties with configuring the Bluetooth (BT) connection to the Omron BP device and the W&W app. Much like the W&W app registration process, pairing the W&W app with the Omron BP device via Bluetooth requires the user to follow a very specific process; not following that process exactly will cause the pairing process to fail. The Omron BT API is simple but inflexible interface with very limited functionality. The protocol requires a smartphone to be in BT mode ready, while the Omron BP device completes a trial BP reading. Upon completion of a BP reading, the Omron device broadcasts its BT signal, allowing the smartphone to pair with the device. Device-pairing is a very specific procedure that is quite simple, consistent, and persistent (as it usually only needs to be done one-time, then the connection is remembered by the smartphone); however, the BT pairing procedure will fail if the exact sequence is not followed. Users expressed issues with the BT pairing process, yet in each instance, they were able to go back to the documentation and follow the process to make a successful BT connection. Since the Omron BT API does not enable a robust interface for error handling and system feedback, the only means to remedy this user concern for BT device-pairing was to further enhance the documentation and accompany the instructions with online video instructions and real-time user support.

Use Case 3: Twice-Daily Blood Pressure Readings using the W&W app

Usability testers were instructed to complete two blood pressure readings in the a.m. (one minute apart) and two BP readings in the p.m. per a specific documented test protocol (as defined by the American Heart Association) using the W&W app. The BP exam reading procedure included placing the Omron cuff on their bicep, sitting still, and conducting two BP reading, and then transferring those reading to their smartphone via the W&W app. Users evaluated the testing procedure and the associated documentation.

Most all users (7/8 – 87.5%) rated the BP exam process as intuitive and easy to use. Two users expressed some confusion with the sequence of events required to make a successful BP reading, specifically, “Do we conduct a BP reading on the Omron device and then transfer to the W&W app, or do we select the W&W app and then do a BP reading?” However, all users were able to refer to the documentation to resolve the confusion and proceed with successfully conducting BP readings. One stated, “Once I understood what I needed to do, it was very easy. I think I missed a written instruction in the beginning which caused a little challenge.” User feedback for this use case prompted further development of more elaborate instructions with specific images from the device and W&W app to fortify the instructions for users. Once users had completed a couple BP exams, users for all age bands quickly habituated and were able to conduct further BP exams without use of any documentation.

Use Case 4: Evaluation of Overall Wise&Well Application Performance

Following a minimum of four consecutive days conducting twice-daily blood pressure exams, usability testers were asked to complete an online survey designed to evaluate the overall functionality and user experience of the system.

The Usability Test proved to be a very productive method for the screening and validation of the integrated technology-mediated solution (W&W app and Omron BP monitor) that was used in the Group 2 blood pressure exam workflow. The usability study identified some specific software issues and workflow integration issues that were able to be resolved prior to the start of the blood pressure exam workflow trial.

It was significant to observe that the lowest ratings for the integrated technology were evidenced in the first two use cases: Download and Install, and W&W app setup with Omron and Registration. Once the users were up and running, the overall operation of twice-daily blood pressure readings indicated the integrated technology (the W&W app and Omron BP monitor) was rated by usability participants as higher (6 users rated=excellent, 2 users rated=good) than the initial set (5 users rated=good, one user rated=neutral). The overall observations are represented in the graph in Fig. 43.

Usability test participants indicated that the app download and install process was a bit confusing, which was attributed to the distribution of “test” software required by the test processes mandated by Apple and Google for their respective iPhone and Android smartphone devices. Typical app users are not required to access and download software from

Apple/Google test platforms; this new “test” download process increased confusion with user. Additionally, the registration process for the W&W app and subsequent Bluetooth paring process with the Omron BP monitor was a unique process that was structured and had limited error recovery when users deviated from the set procedures.

Following the W&W install and Bluetooth-pairing of the Omron BP monitor, users then needed to familiarize themselves with the twice-daily BP reading process using the integrated technology. There was some minor confusion associated with the BP reading sequence with users; however, once the users completed a couple of blood pressure readings, they were very quick to habituate the process into a repeatable routine that could be repeated consistently without the need for documentation or other outside assistance. This usability data did present some concerns since the W&W registration process and Omron Bluetooth pairing process were both required process that had limited flexibility. This prompted the development of more elaborate documentation of the process and real-time access to the documentation from the W&W app via a website.

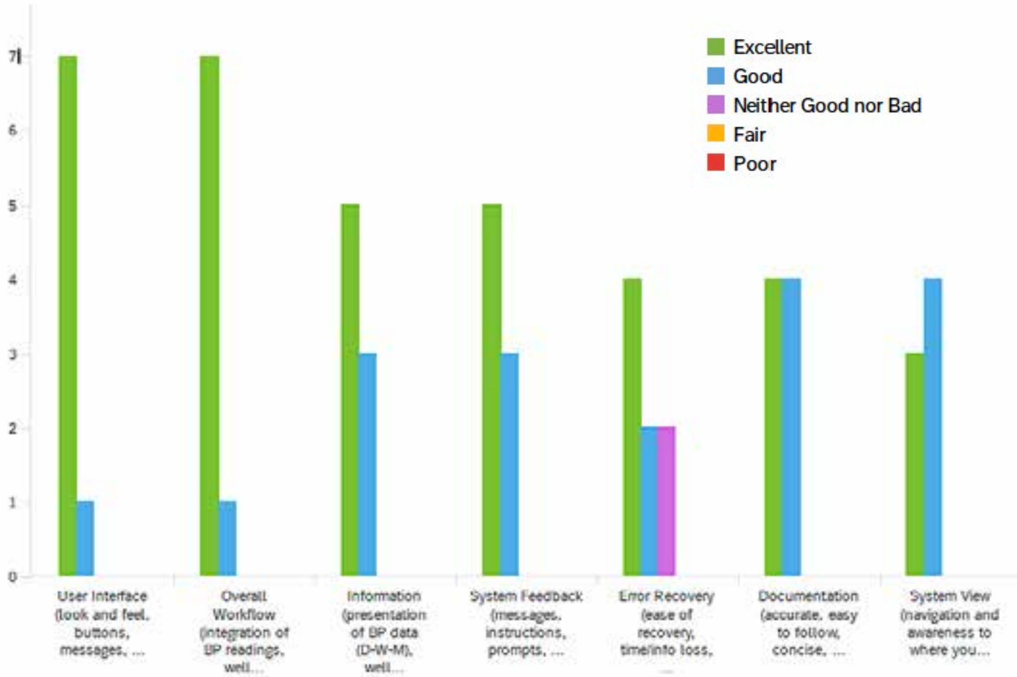


Figure 47: Usability Test Summary - Wise&Well App, Bondy 2020

5.7. CS-AF Hypertension Exam Workflow Survey Data Analysis

5.7.1. CS-AF Workflow Analysis

The Collaborative Space Analysis Framework (CS-AF) incorporates survey data and analysis methodology from five key perspectives: Content, Process, Technology, Attitudes & Behavior, and Outcomes. Detailed discussion of the analysis approach and methodology incorporated in the CS-AF is discussed in the previous section. The specific hypothesis, survey questions, analysis methodology, and summary results for each of the five CS-AF sections is discussed below.

5.7.2. CS-AF Workflow Analysis: Section 1: CONTEXT

The CS-AF integrates the parameters from Model of Coordinated Action (MoCA) [5] as a method to frame the context of both pre- and post- workflow observations. The objective of this aspect of the CS-AF was to capture a standardized snapshot of the participants perspectives related to the context of the current workflow they are familiar with prior to initiating the alternate workflow, so that the change in context between workflow can be observed. The MoCA was used to assess the context of the current-state BP exam workflow compared with both the manual and technology-mediated workflow, using an identical set of MoCA context determinants.

The MoCA [5] introduces a functional approach to describing the context of a collaborative workflow from seven key attributes. The CS-AF integrates the MoCA in place of the TAM "external variables"; the goal is to gain a more precise approach to capture the context of a workflow than the TAM "external variable" approach. The use of external variables in Davis's original TAM model has been criticized as being too vague a construct, which does not provide designers with information necessary to clearly understand the setting and context of users [56], [57]. Integrating the MoCA with the TAM as part of the CS-AF adds precision to the specific descriptive context of the target workflow in a manner that can be consistently evaluated and easily compared. "The seven dimensions of MoCA (i.e., synchronicity, distribution, number of participants, number of communities of practice, nascence, planned permanence, and turnover) provide researchers, developers, and designers with a vocabulary and range of concepts that can be used to tease apart the aspects of a coordinated action that make them easy or hard to design for" [5:191].

CS-AF Evaluation Metrics and H1 Secondary Hypothesis		
Context		
H1.1: Context Hypothesis: It is hypothesized that technology-mediated workflow is more asynchronous and remote, compared with baseline current-state workflow.		
Context	Comparison based on 7 vectors, provides insights into the complexity, volatility, etc. of the collaborative workflow (MoCA) Lee and Paine, CSCW 2015).	
Qualitative Questions	Determinants/Dependent Variables	Measure
	Synchronicity, Physical Distribution, Participants, Communities of Practice, Nascence, Planned Permanence, Turnover	7-point Likert Scale (for each of the 7 Context determinants)
Independent Variables	Group 1 Baseline WF	Group 1 Manual WF
	Group 2 Baseline WF	Group 2 Technology-Mediated WF
Analysis	*r*ANOVA variance analysis and analysis of group means between: Group 1 Baseline vs. Group 1 Manual Workflow and Group 2 Baseline vs. Group 2 Technology WF, and Group 1 Manual WF vs. Group 2 Tech WF. Matched Pairs *t*-Test was conducted for all *r*ANOVA's that generated *p*-values <= .05.	
Subjective Questions	Does this workflow require you to be physically present? Do you considered this workflow to be a new experience or a familiar experience?	

The initial within group rANOVA analysis revealed *p*-values <.05 indicating significant change in the mean values within Group 1 (baseline vs. manual BP exam workflow) and Group 2 (baseline vs. tech-mediated workflow), proving the null hypothesis false and suggesting that the alternative hypothesis is valid.

	CS-AF Context Hypothesis H1.1	Results
H_0 Null Hypothesis μBLWF = μTMWF	The technology-mediated BP exam workflow is not more asynchronous than the baseline workflows and that the CS-AF survey questions and analysis procedure will validate this hypothesis.	False
H_a Alternative Hypothesis μBLWF != μTMWF	The technology-mediated BP exam workflow is more asynchronous than the baseline workflows and that the CS-AF survey questions and analysis procedure will validate this hypothesis.	Valid

The results indicate a significant differences in the way participants define the context of the workflows being compared; this warrants further analysis (matched pairs t-test) within groups to identify the specific determinants that changed substantially from the baseline to the alternate workflow. The rANOVA analysis also revealed that there was an insignificant change in the mean values between Groups 1 and Group 2, indicating that both groups evaluated the contextual difference of their respective workflows in a similar way and that there was minimal variance between the groups.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**	**StdDev**	**p-value**
Group 1 Difference	1. Synchronicity, 2. Physical Distribution, 3. Participants, 4. Communities of Practice, 5. Nascence, 6. Planned Permanence, 7. Turnover			0.029
Group 1 Baseline WF	Group Mean	3.023	0.738	
Group 1 Manual WF	Group Mean	2.480	0.692	
Group 2 Difference	1. Synchronicity, 2. Physical Distribution, 3. Participants, 4. Communities of Practice, 5. Nascence, 6. Planned Permanence, 7. Turnover			0.000
Group 2 Baseline WF	Group Mean	2.794	0.652	
Group 2 Tech WF	Group Mean	2.960	0.659	
Group 2 and Group 1 Difference	1. Synchronicity, 2. Physical Distribution, 3. Participants, 4. Communities of Practice, 5. Nascence, 6. Planned Permanence, 7. Turnover			0.847

Table 14: CS-AF "Context" Group rANOVA and Mean analysis, Bondy 2020

Additional analysis was performed within groups for each of the seven MoCA determinants using matched-pairs t-test to assess within group mean values. This analysis revealed that all but one determinate (planned permanence) showed significant p-values for Group 1, while four out of seven determinants showed significant difference in means values for Group 2.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**		**StdDev**		**p-value**
		BL-WF	**M/T-WF**	**BL-WF**	**M/T-WF**	
Group 1 Baseline WF vs. Group 1 Man. WF	1. Synchronicity	5.600	2.640	2.041	2.177	0.000
	2. Physical Distribution	1.840	3.480	1.724	2.740	0.015
	3. Participants	2.720	1.280	1.208	1.208	0.001
	4. Communities of Practice	1.880	1.040	0.833	0.200	0.000
	5. Nascence	1.920	3.800	1.956	2.291	0.001

Groups/Workflows (Independent Variables)	Determinants (Dependent Variables)	Mean		StdDev		p-value
		BL-WF	M/T-WF	BL-WF	M/T-WF	
	6. Planned Permanence	4.520	3.520	2.383	2.400	0.133
	7. Turnover	2.680	1.600	1.600	1.155	0.014
Group 2 Baseline WF vs. Group 2 Tech. WF	1. Synchronicity	4.560	1.920	2.468	1.935	0.000
	2. Physical Distribution	2.280	4.720	2.011	2.701	0.001
	3. Participants	2.240	1.600	0.879	1.658	0.151
	4. Communities of Practice	2.040	1.360	0.841	0.638	0.005
	5. Nascence	1.600	5.040	1.500	1.670	0.000
	6. Planned Permanence	4.280	3.800	2.354	2.500	0.494
	7. Turnover	2.560	2.280	1.502	1.621	0.510

Table 15: CS-AF - "Context" variance analysis using matched pairs t-test, Bondy 2020.

Group 1 analysis reveals that participants were able to experience significant change in context from the baseline workflow to the manual workflow (control group) on all determinants but planned permanence. Planned permanence is a measure of whether the workflow collaboration is intended to be short-term or long-term; since this was a trial workflow experience, it is understandable that participants might feel that the longevity of this workflow might be limited. The comparative workflow experience for Group 1 was significantly more asynchronous, occurring at the same location, with less participants, in a somewhat routine manner, and with low turnover. Major context differences were observed for synchronicity, number of participants, and turnover, validating the hypothesis and MoCA model for uncovering the change in "context" among group 1 participants.

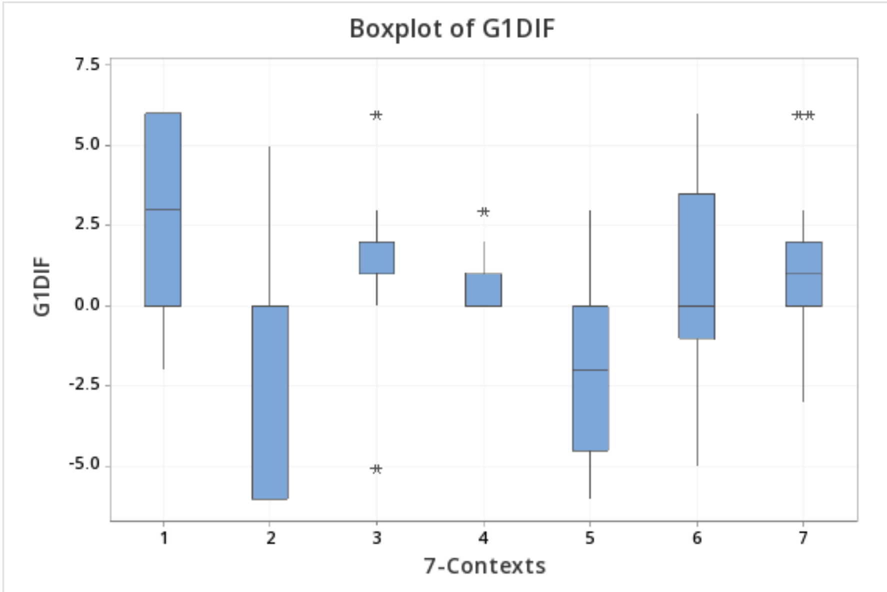


Figure 48: CS-AF within Group 1 Analysis of 7 Context Determinants, Bondy 2020

Group 2 analysis revealed that participants experienced a significant change in the workflows from baseline to technology-mediated; specifically, that the technology-mediated workflow is more asynchronous, is geared to the same location, and has a smaller number of communities of practice, and that they experienced the workflow as new and emerging. Of less significance were the number of participants, planned permanence, and turnover. The null hypothesis proved false, and the alternative hypothesis proved valid with participants perceiving the technology-mediated workflow as more asynchronous than the baseline workflow. Integration of the MoCA determinants successfully into the CS-AF analysis methodology enabled the context evaluation of the workflows and identified significant difference in mean values within Group 1 and Group 2.

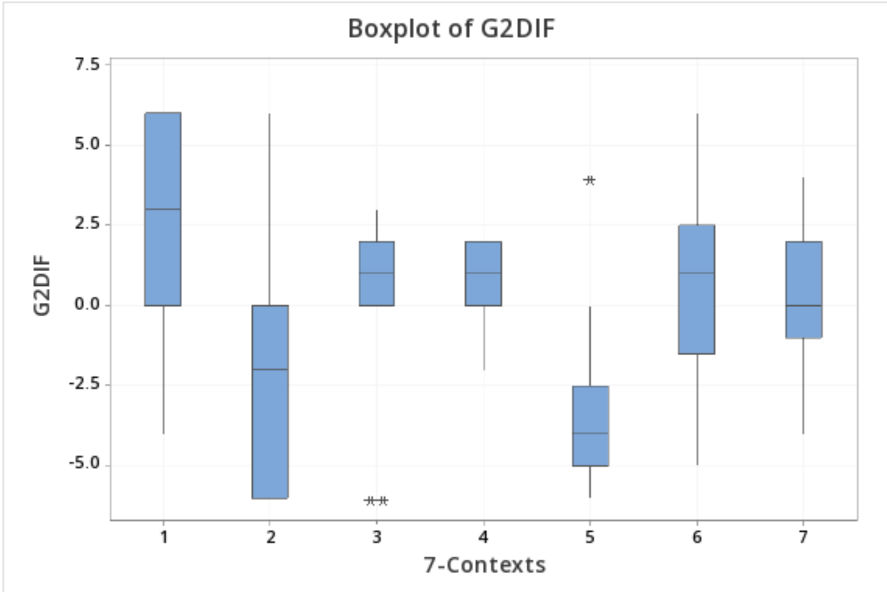


Figure 49: CS-AF within Group 2 Analysis of 7 Context Determinants, Bondy 2020

Summary analysis of group means for all Context determinants is summarized in the graph in Fig. 46.

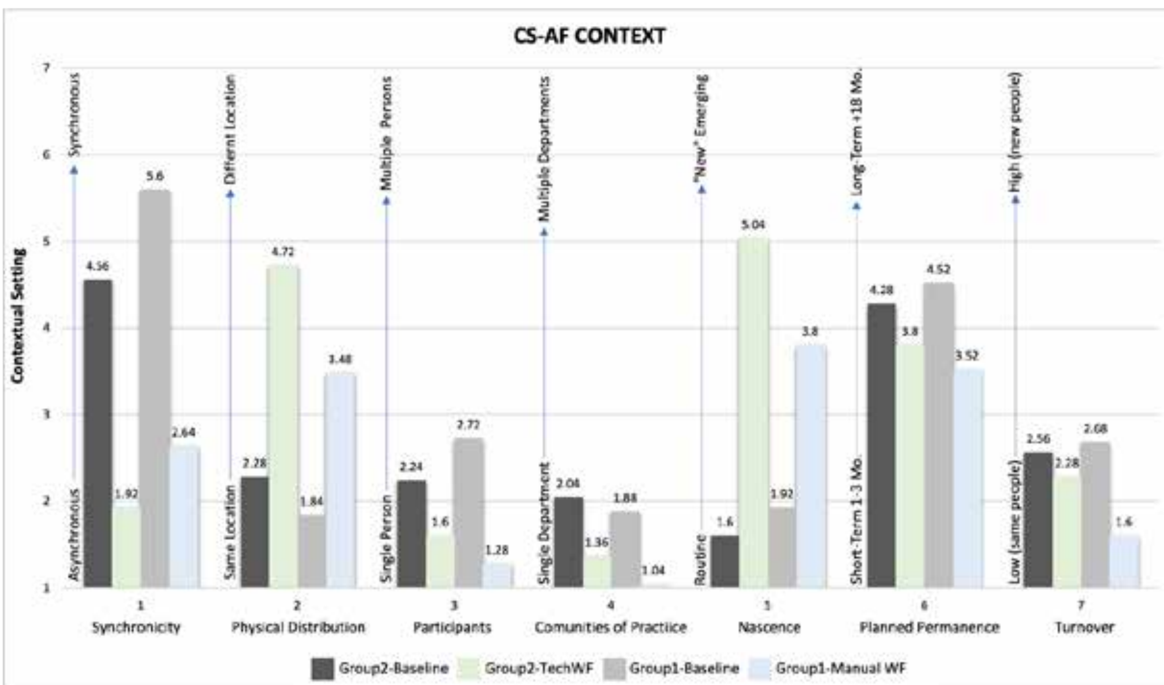


Figure 50: CS-AF "Context" analysis of Group Means, Bondy 2020

Collecting standardized contextual data and analyzing that data with a consistent and predictable methodology enables dependable analysis of each workflow scenario and a viable comparison of means values between the workflows from the perspectives of the same test participants. The CS-AF also incorporates subjective questions that were presented to participants and analyzed to uncover complementary or unrevealed themes that might be apparent to the participants, but not previously identified in the structured survey questions.

Responses to the CS-AF subjective questions did not reveal any new themes from the variances uncovered with the rANOVA and paired t-test.

CS-AF Context Subjective Question 1: 50 participants (25 matched pairs, 2 surveys each) *Does this blood pressure exam require you to be physically present?*	
Group 1: Baseline WF: Yes-24/25, No-1/25	Group 2 Baseline WF: Yes-25/25, No-0/25
Group 1: Manual WF: Yes-24/25, No-1/25	Group 2 Tech-Mediated WF: Yes-17/24, No-7/24
CS-AF Context Subjective Question 2: 50 participants (25 matched pairs, 2 surveys each) *Is this blood pressure exam a "new experience" or a "familiar experience"?*	
Group 1: Baseline WF: Yes-4/25, No-21/25	Group 2 Baseline WF: Yes-1/25, No-24/25
Group 1: Manual WF: Yes-16/25, No-9/25	Group 2 Tech-Mediated WF: Yes-25/25, No-0/25

As expected, participants seemed to be familiar with the blood pressure exam workflow, but not with the notion of "self-care", nor with the use of a smartphone app to conduct the exam and record the information. In Group 2, 25/25 participants responded "yes" to "new experience." One stated that "…this is a new experience. Having my blood pressure taken is not new, but taking it myself with a wrist cuff is; past experiences have used a bicep cuff and been performed by a nurse or a self-serve machine in a pharmacy" W18.24.2M. "Taking my own blood pressure is not new to me, but using the app was new" T45.54.5M.

5.7.3. CS-AF Workflow Analysis: Section 2: PROCESS

The Process element of the CS-AF includes the time series data collection and analysis of the sequential steps (stages) involved in the blood pressure exam workflow. An Industrial Engineering method for pre- and post- time series analysis, Value Stream Mapping (VSM), was used for measuring workflow time and information quality [28], [50]. Using the VSM method, the five discrete steps analyzed that complete a blood pressure exam workflow are; (1) Pre-Visit, (2) Registration, (3) BP Exam, (4) Treatment, and (5) Post-Exam.

The objective of the CS-AF Process element is to capture and analyze the time involved by each group to complete a baseline (traditional) blood pressure exam workflow, compared with an alternate workflow (either the manual or tech-mediated BP exam workflow). Pre- and post- time series data was recorded and analyzed for the exact same five workflow stages for all test participants and their respective workflows. Participants reported actual time series data for each workflow stage, which includes cycle time (i.e., duration of task from start to completion), lag time (i.e., time that the workflow is held up waiting), and total time (i.e., entire time required for a workflow step). Participants also provided estimated times for what they felt were the ideal or "acceptable" times for each of the workflow stage (both cycle-time and lag-time).

<table>
<tr><th colspan="3">CS-AF Evaluation Metrics and H1 Secondary Hypothesis</th></tr>
<tr><th colspan="3">Process</th></tr>
<tr><td colspan="3">H1.2: Process Time Hypothesis: It is hypothesized that technology-mediated workflows are more streamlined (i.e., require less time), when compared with baseline current-state workflows.</td></tr>
<tr><td rowspan="2">Process</td><td colspan="2">Value Stream Mapping (cycle-time & lag-time at each WF step).</td></tr>
<tr><td>Determinant/Dependent Variables</td><td>Measure</td></tr>
<tr><td>Quantitative Questions</td><td>1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam</td><td>Time in seconds for Cycle-Time, Lag-Time, Total Task Time</td></tr>
<tr><td>Analysis:</td><td colspan="2">Group Means for the <u>Task Time</u> and <u>Lag Time</u> for each of the 5 WF stages: Comparison of <u>Actual Mean</u> times and <u>Acceptable Mean</u> times</td></tr>
</table>

	for Group 1 and 2 Baseline WF's, and Group1 Manual WF and Group 2 Tech-Mediated WF	
Qualitative Questions	WF Cycle-Time and Lag-Time Acceptability	7-point Likert Scale (1-very unacceptable – 7 very acceptable)
Independent Variables	Group 1 Baseline WF	Group 1 Manual WF
	Group 2 Baseline WF	Group 2 Technology-Mediated WF
Analysis	*r*ANOVA variance analysis and analysis of group means between: Group 1 Baseline vs. Group 1 Manual Workflow and Group 2 Baseline vs. Group 2 Technology WF, and Group 1 Manual WF vs. Group 2 Tech WF. Matched Pairs *t*-Test was conducted for all rANOVA's that generated *p*-values <= .05.	
Subjective Questions	Is there a particular step in the WF that seemed like a waste of time, elaborate?	

The time series data represents a precise reference for the analysis of unique idiosyncrasies in the workflow related to actual vs. acceptable times for the workflows evaluated. It is hypothesized that technology-mediated workflows are more streamlined (i.e., require less time), when compared with baseline workflow. The objective of the Process section is to analyze quantitative time series data and pinpoint specific performance gains and gaps associated each specific workflow stage for the collaborative workflows evaluated.

	CS-AF Process Hypothesis H1.2	**Results**
H_0 Null Hypothesis ц BLWF = ц TMWF	The technology-mediated workflows are not more streamlined (i.e., require less time), when compared with baseline current-state workflows.	False
H_a Alternative Hypothesis ц BLWF != ц TMWF	The technology-mediated workflows are more streamlined (i.e., require less time), when compared with baseline current-state workflows.	Valid

The data and analysis from the CS-AF Process section will represent the "actual" and "acceptable" times of the participants and their feelings associated with the relevance and importance of the information quality for their respective workflows. In addition to the time series analysis, CS-AF data was collected and analyzed from two survey questions focused on the information quality throughout the respective workflows. Specifically, participants were asked to rate (7-point Likert scale) "how relevant" and "how important" the information was at each stage in the workflow. These questions were analyzed and compared with the time series data with the goal of capturing further insights from participants on the importance that information quality plays in the collaborative workflow experience. Finally, the two subjective questions included in the CS-AF Process section were also analyzed with the objective to uncover further insights regarding the feeling's participants had towards improving time and information quality in the workflows.

Test participants self-reported actual cycle-times and lag-times times for each stage of the workflows. The summary table below indicates a significant net workflow time reduction for both the manual and tech-mediated workflows, compared with their respective baseline workflows. Group 1 participants reported 797% overall reduction in total BP exam workflow time, from 68.52 minutes to 8.60 minutes, while Group 2 participants reported 359% overall reduction in total BP exam workflow, time from 69.62 minutes to 19.40 minutes. It is important to note that the total workflow times reported for both Group 1 and 2 baseline are similar (with a 1.1-minute difference), indicating that both groups recorded BP exam workflow times consistently. Of further significance is workflow stage 3 cycle-time for the BP exam itself, which represented the least significant time reduction for both Group 1 and 2. This indicates that the primary source of workflow time reduction reported was represented in all stages of the workflow aside from the actual process of conducting a BP exam reading, presenting opportunities for workflow optimization across other stages in the workflow.

BP Exam Workflow Actual Times (self-reported times in minutes)						
BP Exam Workflow Stage Cycle-Time (CT) and Lag Time (LT)	Group 1- Baseline WF	Group 1 - Manual WF	Group 1 - Difference	Group 2- Baseline WF	Group 2- Technology WF	Group 2 - Difference
1. Pre-Visit CT	8.60	0.44	8.16	9.92	2.28	7.64
1. Pre-Visit LT	4.40	0.36	4.04	4.88	0.88	4.00
2. Registration CT	4.56	0.60	3.96	4.52	1.72	2.80
2. Registration LT	10.04	0.48	9.56	11.64	1.72	9.92
3. BP Exam CT	3.88	3.52	0.36	4.68	3.22	1.46
3. BP Exam LT	8.16	1.04	7.12	7.82	1.12	6.70
4. Treatment CT	9.32	0.76	8.56	10.52	3.86	6.66

BP Exam Workflow Actual Times (self-reported times in minutes)						
BP Exam Workflow Stage Cycle-Time (CT) and Lag Time (LT)	Group 1-Baseline WF	Group 1 - Manual WF	Group 1 - Difference	Group 2-Baseline WF	Group 2-Technology WF	Group 2 - Difference
4, Treatment LT	8.00	0.40	7.60	7.68	1.60	6.08
5. Post-Exam CT	6.08	0.52	5.56	3.12	1.72	1.40
5. Post-Exam Post LT	5.48	0.48	5.00	4.84	1.28	3.56
Sub Totals	68.52	8.60	59.92	69.62	19.40	50.22

Table 16: BP Exam Workflow Actual times, Group 1 and 2 (estimate self-reported), Bondy 2020

The largest time reduction for both Group 1 and 2 was represented in the Stage 2 registration lag time (9.56 and 9.92 respectively), representing the time saved by participants for waiting after registration prior to the traditional BP exam.

Further time series analysis was conducted with respect to the "acceptable" times that participants suggested for each stage in the workflow. This time series data reflects group mean values as a participant reference point for the ideal acceptable time for each stage in the workflow. Comparison between the actual workflow times and the acceptable times suggests the optimum goal for target workflow times to meet user acceptance. Group 1 time series data reveals that actual mean times, compared with acceptable workflow, varied by 61.9%, meaning that participants felt that to be acceptable; in other words, the baseline BP workflow should need to be optimized by approximately by 26 minutes. Similarly, the total manual BP workflow (8.60 minutes), which improved 794% from the baseline (68.52 minutes), would need additional process improvement of 24.3% (1.68 minutes) to attain optimal level of acceptably by test participants.

Group 1: Within Group Actual vs. Acceptable BP Exam Workflow Time Series Analysis (minutes)						
BP Exam Workflow Stage Cycle-Time (CT) and Lag Time (LT)	Group 1-Baseline Act. WF	Group 1 - Manual Act. WF	Group 1 – Act. WF Difference	Group 1-Baseline Acc. WF	Group 1-Manual Acc.WF	Group 1 – Acc. WF Difference
1. Pre-Visit CT	8.60	0.44	8.16	4.80	0.44	4.36

Group 1: Within Group Actual vs. Acceptable BP Exam Workflow Time Series Analysis (minutes)						
BP Exam Workflow Stage Cycle-Time (CT) and Lag Time (LT)	Group 1- Baseline Act. WF	Group 1 - Manual Act. WF	Group 1 – Act. WF Difference	Group 1- Baseline Acc. WF	Group 1- Manual Acc.WF	Group 1 – Acc. WF Difference
1. Pre-Visit LT	4.40	0.36	4.04	1.76	0.12	1.64
2. Registration CT	4.56	0.60	3.96	3.28	0.36	2.92
2. Registration LT	10.04	0.48	9.56	3.04	0.12	2.92
3. BP Exam CT	3.88	3.52	0.36	4.80	3.48	1.32
3. BP Exam LT	8.16	1.04	7.12	3.20	0.76	2.44
4. Treatment CT	9.32	0.76	8.56	10.6	1.00	9.60
4, Treatment LT	8.00	0.40	7.60	3.80	0.12	3.68
5. Post-Exam CT	6.08	0.52	5.56	5.60	0.40	5.20
5. Post-Exam Post LT	5.48	0.48	5.00	1.56	0.12	1.44
Sub Totals	68.52	8.60	59.92	42.44	6.92	35.52

Table 17:BP Exam Workflow Actual vs. Acceptable times, Group 1 (estimate self-reported), Bondy 2020

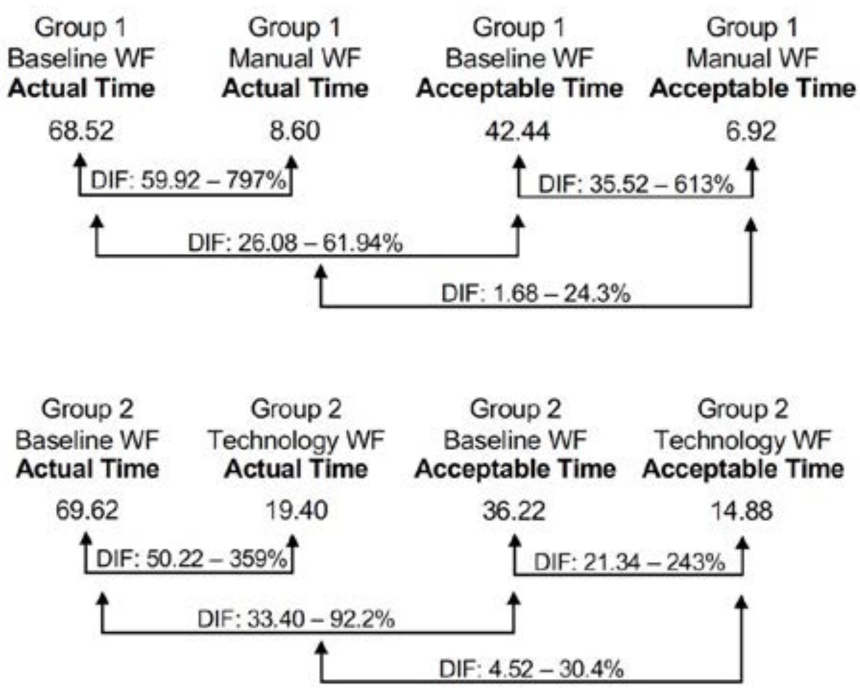
Group 2 time series data reveals that mean times for actual compared with acceptable workflow times varied by 92.2%, meaning that participants felt that to be acceptable; in other words, that the baseline BP workflow should be reduced approximately by 33.40 minutes. Similarly, the total tech-mediated BP workflow (19.40 minutes), which improved 359% from the baseline (69.62 minutes), would need additional process improvement of 30.4% (4.52 minutes) to attain optimal level of acceptably by test participants.

Group 2: Within Group Actual vs. Acceptable BP Exam Workflow Time Series Analysis (minutes)						
BP Exam Workflow Stage Cycle-Time (CT) and Lag Time (LT)	Group 2- Baseline Act. WF	Group 2- Technology Act. WF	Group 2 – Act. WF Difference	Group 2- Baseline Acc. WF	Group 2- Technology Acc. WF	Group 2 – Acc. WF Difference
1. Pre-Visit CT	9.92	2.28	7.64	5.32	1.04	4.28
1. Pre-Visit LT	4.88	0.88	4.00	1.72	0.40	1.32
2. Registration CT	4.52	1.72	2.80	2.76	1.16	1.60
2. Registration LT	11.64	1.72	9.92	3.40	1.20	2.2
3. BP Exam CT	4.68	3.22	1.46	3.36	3.14	0.22
3. BP Exam LT	7.82	1.12	6.70	2.50	1.32	1.18
4. Treatment CT	10.52	3.86	6.66	8.76	3.78	4.98
4, Treatment LT	7.68	1.60	6.08	3.36	1.60	1.76
5. Post-Exam CT	3.12	1.72	1.40	3.52	0.88	2.64

Group 2: Within Group Actual vs. Acceptable BP Exam Workflow Time Series Analysis (minutes)						
BP Exam Workflow Stage Cycle-Time (CT) and Lag Time (LT)	Group 2-Baseline Act. WF	Group 2-Technology Act. WF	Group 2 – Act. WF Difference	Group 2-Baseline Acc. WF	Group 2-Technology Acc. WF	Group 2 – Acc. WF Difference
5. Post-Exam Post LT	4.84	1.28	3.56	1.52	0.36	1.16
Sub Totals	69.62	19.40	50.22	36.22	14.88	21.34

Table 18: BP Exam Workflow Actual vs. Acceptable times, Group 2 (estimate self-reported), Bondy 2020

Further time series analysis between Group1 and Group 2 reveals that test participants responded in a similar manner with respect to the baseline workflows. Group 1 baseline workflow was 68.52 minutes and Group 2 baseline workflow was 69.62, indicating that the two randomly selected groups responded in a similar fashion with respect to the standard baseline blood pressure exam, with only a 1.10-minute difference in the overall baseline group means. Both groups exhibited similar workflow improvements from their baseline workflows and their respective alternate workflows, with the most dramatic overall improvement evidenced in Group 1 manual workflow.



It is interesting to observe that the acceptable times for Group 2, tech-mediated workflow was 14.88 minutes, compared with 6.92 minutes acceptable times for Group 1 manual workflow, indicating participants seem more accepting of longer workflow times when advanced technology is incorporated into the workflow. The acceptability of 7.96 minutes more time (115%) represents an increased tolerance-level that participants acknowledged as an acceptable trade-off for added performance enabled through the technology. The mean data from Group 2 reveals that participants believe that acceptable time should still be optimized by 5.52 minutes (30.4%), yet the mean acceptable time for Group 2 was 14.88 minutes, as opposed to 6.92 minutes for the Group manual workflow.

Further analysis of the time series data at the workflow stage within each group and between Group 1 and Group 2 indicates that largest opportunity for workflow optimization are in Stages 1. Pre-visit, 4. Treatment, and 5. Post-Exam for both Group1 and Group 2. The most optimized stage of the workflow for both Group 1 and 2 was Stage 3. BP Exam itself. This time series data indicates that optimization of the upstream and downstream stages in the workflow are pivotal to delivering a holistic collaborative workflow that meets the expectation of the participants.

Group 1 and Group 2 Comparison Acceptable BP Exam WF Times						
BP Exam Workflow Stage Cycle-Time (CT) and Lag Time (LT)	Group 1- Baseline Acc. WF	Group 1- Manual Acc. WF	Group 1 - Difference	Group 2- Baseline Acc. WF	Group 2- Technology Acc. WF	Group 2 - Difference
1. Pre-Visit CT	4.80	0.44	4.36	5.32	1.04	4.28
1. Pre-Visit LT	1.76	0.12	1.64	1.72	0.4	1.32
2. Registration CT	3.28	0.36	2.92	2.76	1.16	1.60
2. Registration LT	3.04	0.12	2.92	3.40	1.20	2.20
3. BP Exam CT	4.80	3.48	1.32	3.36	3.14	0.22
3. BP Exam LT	3.20	0.76	2.44	2.50	1.32	1.18
4. Treatment CT	10.6	1.00	9.60	8.76	3.78	4.98
4. Treatment LT	3.80	0.12	3.68	3.36	1.60	1.76

Group 1 and Group 2 Comparison Acceptable BP Exam WF Times						
BP Exam Workflow Stage Cycle-Time (CT) and Lag Time (LT)	Group 1- Baseline Acc. WF	Group 1- Manual Acc. WF	Group 1 - Difference	Group 2- Baseline Acc. WF	Group 2- Technology Acc. WF	Group 2 - Difference
5. Post-Exam CT	5.60	0.40	5.20	3.52	0.88	2.64
5. Post-Exam LT	1.56	0.12	1.44	1.52	0.36	1.16
Sub Totals	42.44	6.92	35.52	36.22	14.88	21.34

Table 19: BP Exam Workflow Group 1 vs. Group Actual times comparison (estimate self-reported), Bondy 2020

The CS-AF also included further Process analysis of participants perspectives regarding the "acceptability" process times and the importance of "information quality" for each stage in the workflows that were evaluated. This aspect of the analysis was designed to uncover participant ratings for acceptability and information quality in order to better understand the relationship of participants' opinions related to the actual and estimated time series data they recorded.

Repeat measure ANOVA was conducted to assess the mean values within and between groups for acceptable times (cycle times and lag times) and information quality (relevance and importance). Acceptability of cycle time rANOVA analysis across all group scenarios indicated significant difference in mean values, with p-values of 0.00 for within and between all groups.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**	**StdDev**	**p-value**
Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.000
Group 2 Baseline WF	Group Mean	4.840	1.290	
Group 2 Tech WF	Group Mean	5.792	1.196	
Group 1 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.000
Group 1 Baseline WF	Group Mean	4.544	1.093	
Group 1 Manual WF	Group Mean	5.568	1.509	
Group 1 vs. Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.000

Table 20: rANOVA analysis of Acceptability of Cycle-Time and Lag-Time by Workflow Stage, Bondy 2020

The rANOVA analysis substantiates the need for a deeper probe at the workflow stage level using matched pairs *t*-test to identify within group differences in mean values and to further corroborate the null hypothesis false and the alternative hypothesis valid. The time series data proved that the alternative workflows were more streamlined (as hypothesized), that these expanded questions and analysis at the workflow stage level will indicate where in the workflow participants felt times were acceptable, and how important and relevant the information quality was at each stage.

Additional analysis was performed within groups for acceptable cycle times at each of the five stages in the workflow using matched-pairs t-test to assess within group variance. This analysis revealed significant p-values, indicating significantly more acceptable workflow times for Stages 1, 3, and 4 for Group 1, while Group 2 analysis shows significance in workflow Stages 1, 2, 3, 5, further substantiating the improvement and time acceptability of the alternative workflows, compared with their respective baseline workflows. Between group analysis also indicates that the acceptable times for Group 2 tech-mediated workflow was more acceptable than the Group 1 manual workflow, even though the overall workflow times for the manual workflow was less than for the tech-mediated workflow.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**		**StdDev**		**p-value**
		BL-WF	**M/T-WF**	**BL-WF**	**M/T-WF**	
Group 1 Baseline WF vs. Group 1 Man. WF	1. Pre-Visit	4.680	5.560	1.345	1.197	0.040
	2. Registration	4.520	5.440	1.610	1.917	0.108
	3. BP Exam	4.720	6.040	1.400	1.541	0.005
	4. Treatment	4.360	5.520	1.630	1.806	0.025
	5. Post-Exam	4.440	5.280	1.502	1.792	0.079
Group 2 Baseline WF vs. Group 2 Tech. WF	1. Pre-Visit	4.560	5.800	1.557	1.756	0.014
	2. Registration	4.720	5.840	1.745	1.519	0.024
	3. BP Exam	5.320	6.000	1.215	1.258	0.038
	4. Treatment	5.040	5.720	1.399	1.399	0.081
	5. Post-Exam	4.056	5.600	1.446	1.354	0.008

Table 21: Matched Pairs t-test analysis of Acceptability of Cycle-Time by Workflow Stage, Bondy 2020

Repeat measure ANOVA was conducted to assess the mean values within and between groups for acceptable lag times (i.e., wait time) between stages. Acceptability of lag time rANOVA analysis within Group 2 indicated significant mean value differences, with p-values of 0.046. Further analysis using matched-pairs t-test was conducted at the workflow stage for all groups, with specific interest in the data from Group 2.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**	**StdDev**	**p-value**
Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.046
Group 2 Baseline WF	Group Mean	4.128	0.249	
Group 2 Tech WF	Group Mean	5.688	0.239	
Group 1 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.074
Group 1 Baseline WF	Group Mean	3.856	0.247	
Group 1 Manual WF	Group Mean	5.256	0.357	
Group 1 vs. Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.385

Table 22: rANOVA analysis of Acceptability of Lag Time by Workflow Stage, Bondy 2020

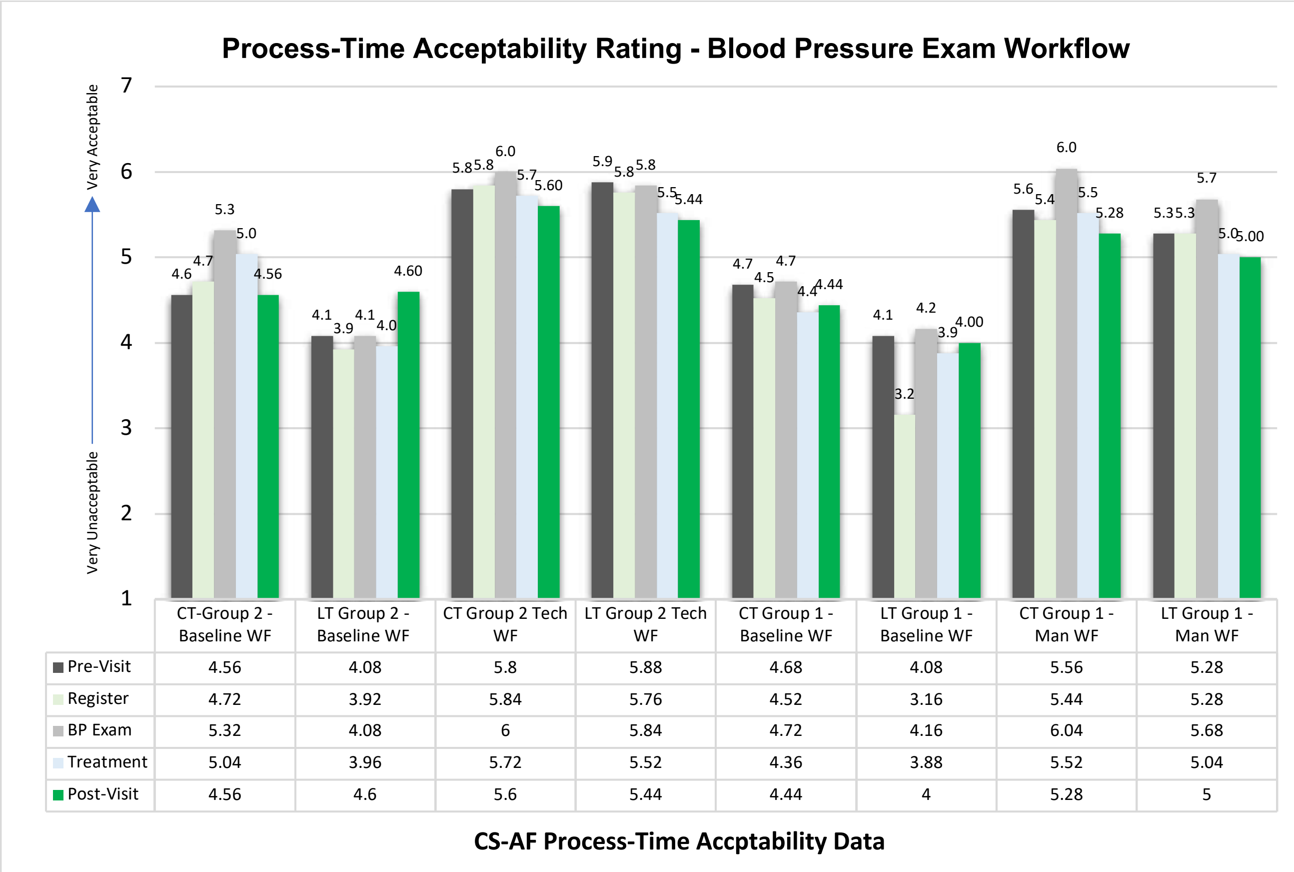
The acceptable lag times at each of the five stages in the workflow was analyzed using matched-pairs t-test to assess within group variance. Both Group 1 and 2 show significant difference in mean values at all workflow stages, except for the post-exam Stage 5. Group 2 variances indicated lower p-values than Group 1 for all stages, indicating the lag times were overall more acceptable for Group 2 technology-mediated workflow than for Group 1 manual workflow.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**		**StdDev**		**p-value**
		BL-WF	**M/T-WF**	**BL-WF**	**M/T-WF**	
Group 1 Baseline WF vs. Group 1 Man. WF	1. Pre-Visit	4.080	5.280	1.525	1.990	0.034
	2. Registration	3.160	5.280	1.599	1.948	0.001
	3. BP Exam	4.160	5.680	1.519	1.865	0.006
	4. Treatment	3.880	5.040	1.536	2.071	0.027
	5. Post-Exam	4.000	5.000	1.780	2.041	0.074
Group 2 Baseline	1. Pre-Visit	4.080	5.880	1.470	1.424	0.000
	2. Registration	3.920	5.760	1.730	1.300	0.001

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**		**StdDev**		**p-value**
		BL-WF	**M/T-WF**	**BL-WF**	**M/T-WF**	
WF vs. Group 2 Tech. WF	3. BP Exam	4.080	5.840	1.498	1.546	0.000
	4. Treatment	3.960	5.520	1.338	1.388	0.002
	5. Post-Exam	4.600	5.440	1.414	1.387	0.065

Table 23: Matched Pairs t-test analysis of Acceptability of Lag Time by Workflow Stage, Bondy 2020

It is interesting to note that, although the cycle and lag times were improved and viewed more acceptable by both Group 1 and 2, there still remains opportunity for a significant opportunity to improve the time optimization in the BP exam workflow, specifically in the workflow stages preceding Stage 3 (BP exam) and the post-exam workflow stages. This data suggests that, in order for participants to be completely accepting of the workflow times, all stages in the workflow need to be optimized, not only the stage in the workflow where the primary technology has been implemented. The summary bar graph represents the group mean ratings of time acceptability across each stage in the workflow for Group 1 baseline and manual workflows, and for Group 2 baseline and tech-mediated workflows.



	CT-Group 2 - Baseline WF	LT Group 2 - Baseline WF	CT Group 2 Tech WF	LT Group 2 Tech WF	CT Group 1 - Baseline WF	LT Group 1 - Baseline WF	CT Group 1 - Man WF	LT Group 1 - Man WF
Pre-Visit	4.56	4.08	5.8	5.88	4.68	4.08	5.56	5.28
Register	4.72	3.92	5.84	5.76	4.52	3.16	5.44	5.28
BP Exam	5.32	4.08	6	5.84	4.72	4.16	6.04	5.68
Treatment	5.04	3.96	5.72	5.52	4.36	3.88	5.52	5.04
Post-Visit	4.56	4.6	5.6	5.44	4.44	4	5.28	5

Figure 51: CS-AF Acceptability of Total Workflow Times (cycle + lag times) for all Groups, Bondy 2020

The CS-AF includes two questions regarding the relevance and importance of Information Quality across all stages in the workflows that were evaluated. It is hypothesized that the technology-mediated workflow would facilitate collaborative exchange of information and that the information would be viewed as and more relevant for participants. The CS-AF survey questions and subsequent analysis was aimed at evaluating the impact that technology enhanced workflow makes on information quality, as represented by participants.

CS-AF Evaluation Metrics and H1 Secondary Hypothesis
Process
H1.3: Information Quality Hypothesis: It is hypothesized that technology-mediated workflow delivers better information quality, when compared with baseline current-state workflows.

CS-AF Evaluation Metrics and H1 Secondary Hypothesis		
Process		
Process Quality	Qualitative evaluation of the importance and relevance of the information available at each step of the workflow.	
	Determinant/Dependent Variables	Measure
Qualitative Questions	Information <u>relevance</u> for each WF stage	7-point Likert Scale (1-very irrelevant – 7-very relevant)
	Information <u>importance</u> for each WF stage	7-point Likert Scale (1-very unimportant – 7-very important)
Independent Variables	Group 1 Baseline WF	Group 1 Manual WF
	Group 2 Baseline WF	Group 2 Technology-Mediated WF
Analysis	*r*ANOVA variance analysis and analysis of group means between: Group 1 Baseline vs. Group 1 Manual Workflow and Group 2 Baseline vs. Group 2 Technology WF, and Group 1 Manual WF vs. Group 2 Tech WF. Matched Pairs *t*-Test was conducted for all rANOVA's that generated *p*-values <= .05.	
Subjective Questions	Is there a particular step in the WF that seemed confusing (poor instructions, not intuitive)?	

Initial rANOVA analysis was conducted to assess the relevance of information at each workflow stage for all workflows within and between groups. The rANOVA analysis indicated no significant difference in mean values between Group 1 and Group 2, and within Group 2. This data represents minimal change in participants' perspectives of the relevance of the information between the baseline and the technology-mediated workflows. The only significant difference in mean values revealed through the rANOVA analysis was within Group 1 between the baseline and manual workflow, as evidenced with a p-value of 0.008.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**	**StdDev**	**p-value**
Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.176
Group 2 Baseline WF	Group Mean	2.776	0.901	
Group 2 Tech WF	Group Mean	3.160	1.420	
Group 1 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.008
Group 1 Baseline WF	Group Mean	2.832	0.816	
Group 1 Manual WF	Group Mean	4.016	1.500	
Group 1 vs. Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.185

Table 24: rANOVA analysis of Information Relevance by Workflow Stage, Bondy 2020

The rANOVA analysis revealed no significance between the baseline and technology mediated workflow regarding information relevance, thus proving the null hypothesis value and the hypothesis false that the tech-mediated workflow would deliver better information quality, compared with the baseline workflow. These results are somewhat surprising, since the Wise&Well app delivers blood pressure data immediately to participants and the BP data is visualized in a graph for daily, weekly, and monthly comparisons. Further analysis was conducted using paired t-tests to identify the specific degree of change between the workflow for both groups. In addition, the rANOVA did indicate a significant difference in mean values within Group 1; further analysis using matched pairs t-test was conducted to pinpoint the specific stage in the workflow where the information quality improved for Group 1 and to better understand why there was minimal change for Group 2.

	CS_AF Process Hypothesis H1.3	**Results**
H_0 Null Hypothesis ц BLWF = ц TMWF	The technology-mediated workflow does not deliver better information quality, when compared with baseline current-state workflows.	Valid
H_a Alternative Hypothesis ц BLWF != ц TMWF	The technology-mediated workflow delivers better information quality, when compared with baseline current-state workflows.	False

Although the hypothesis proved false for information relevance at the Group level, it is interesting to note that participants reported improvement at each stage for both Group 1 and Group 2. The paired t-test revealed that the Group 1 difference in mean values was only significant for Stage 1, 4, and 5; for Group 2, only stage 4 showed significance. This data indicates some minor improvement in information relevance, but it was not significant enough for participants to acknowledge a breakthrough in this area. Further analysis of the open-ended subjective questions asked for in this segment identifies that participants were not fully satisfied with the way BP data was presented visually and that they wanted more data visualization options for their BP reading than the system provided. Participants rated a greater improvement in information relevance for workflow Stage 3 (BP exam) for Group 2 (BL WF: 2.16 – Tech-mediated WF: 2.4) vs. Group 1 manual workflow (BL WF: 2.4 – Manual WF: 2.56). This data indicates that the technology does improve the information relevance, but in order to deliver significant improvement in information relevance, technology improvements need to include comprehensive user experiences and flexibility in the configuring of the user interfaces which are intuitive and easy to adjust to the unique proclivities of a wide range of users. Even though participants like to have real-time BP data, they wanted more control and visualization options regarding their BP data in the app.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**		**StdDev**		**p-value**
		BL-WF	**M/T-WF**	**BL-WF**	**M/T-WF**	
Group 1 Baseline WF vs. Group 1 Man. WF	1. Pre-Visit	3.240	4.800	1.393	1.915	0.007
	2. Registration	4.120	4.840	1.691	1.841	0.145
	3. BP Exam	2.400	2.560	1.118	1.873	0.733
	4. Treatment	1.800	3.680	0.866	2.212	0.001
	5. Post-Exam	2.600	4.200	1.323	2.160	0.001
Group 2 Baseline WF vs. Group 2 Tech. WF	1. Pre-Visit	3.440	3.520	1.734	1.782	0.852
	2. Registration	3.680	3.960	1.865	1.881	0.493
	3. BP Exam	2.160	2.400	0.943	1.958	0.581
	4. Treatment	1.800	2.880	1.080	1.922	0.014
	5. Post-Exam	2.800	3.040	1.225	1.859	0.555

Table 25: Matched Pair t-test analysis of Information Relevance by Workflow Stage, Bondy 2020

Similar to the analysis of information relevance, initial rANOVA analysis was conducted to assess the importance of information at each workflow stage for all workflows within and between groups. The rANOVA analysis indicated no significant difference in mean values between Group 1 and Group 2, and within Group 2. This data represents minimal change in participants' perspectives of the importance of the information between the baseline and the technology-mediated workflows. The only significant difference in mean values revealed through the rANOVA analysis was within Group 1 between the baseline and manual workflow, evidenced with a p-value of 0.000.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**	**StdDev**	**p-value**
Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.323
Group 2 Baseline WF	Group Mean	2.840	0.961	
Group 2 Tech WF	Group Mean	3.200	1.394	
Group 1 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.000
Group 1 Baseline WF	Group Mean	2.712	0.744	
Group 1 Manual WF	Group Mean	3.944	1.340	
Group 1 vs. Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.167

Table 26: rANOVA analysis of Information Importance by Workflow Stage, Bondy 2020

The rANOVA analysis indicated a significant difference in mean values within Group 1. Further analysis using matched pairs t-test was conducted to pinpoint the specific stage in the workflow where the information quality improved for Group 1 and to better understand why there was minimal change for Group 2. rANOVA analysis revealed no significance between the baseline and technology-mediated workflow regarding information importance further, confirming the null hypothesis valid and the hypothesis false that the tech-mediated workflow would deliver better information quality, compared with the baseline workflow.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**		**StdDev**		**p-value**
		BL-WF	**M/T-WF**	**BL-WF**	**M/T-WF**	
Group 1 Baseline WF vs. Group 1 Man. WF	1. Pre-Visit	3.560	4.720	1.530	1.720	0.013
	2. Registration	4.320	4.720	1.773	1.720	0.296
	3. BP Exam	2.000	2.440	0.913	1.685	0.177
	4. Treatment	1.520	3.680	0.714	2.036	0.000
	5. Post-Exam	2.160	4.160	1.106	2.055	0.000
Group 2 Baseline WF vs. Group 2 Tech. WF	1. Pre-Visit	3.640	4.080	1.846	1.706	0.210
	2. Registration	4.040	4.120	1.620	1.810	0.828
	3. BP Exam	2.120	2.160	1.201	1.864	0.907
	4. Treatment	1.720	2.520	1.308	1.711	0.036
	5. Post-Exam	2.680	3.120	1.314	1.833	0.252

Table 27: Matched Pairs t-test analysis of Information Importance by Workflow Stage, Bondy 2020

The analysis of information quality indicates that, although there was minor positive movement in both information relevance and importance, the advancements were not significant enough to satisfy participants for the technology-mediated workflow. It is apparent by the survey data and from the subjective responses that the majority of participants felt that some areas in the baseline workflow were time-consuming; this was mostly related to lag time or waiting time. Technology-mediated workflow participants appreciated the real-time collection and graphical representation of their blood pressure data, yet they felt like the user experience could be more customizable to their unique interests in looking at the data from various views and with association to other interesting variables, such as BP-related wellness measures including as salt intake. Themes analyzed from the open-ended subjective response questions suggest that future UX efforts for remote telehealth apps such as the BP exam workflow would be best designed in an iterative manner over time, with lead users refining the user interface, as well as developing appropriate options for customization of the user experience.

CS-AF Process Subjective Question 1: 50 participants (25 matched pairs, 2 surveys each) *Is there a part of the BP exam workflow that seemed time consuming?*	
Group 1: Baseline WF: Yes-21/24, No-3/24	Group 2 Baseline WF: Yes-22/24, No-2/24
Group 1: Manual WF: Yes-15/25, No-10/25	Group 2 Tech-Mediated WF: Yes-14/24, No-10/24
CS-AF Process Subjective Question 2: 50 participants (25 matched pairs, 2 surveys each) *Is there a part of the workflow that seemed confusing (poor instructions, not intuitive)?*	
Group 1: Baseline WF: Yes-5/22, No-17/22	Group 2 Baseline WF: Yes-10/22, No-12/22
Group 1: Manual WF: Yes-4/25, No-21/25	Group 2 Tech-Mediated WF: Yes-16/25, No-9/25
CS-AF Process Subjective Question 3: 50 participants (25 matched pairs, 2 surveys each) *Do you feel there is an opportunity to reduce the time associated in the BP exam workflow?*	
Group 1: Baseline WF: Yes-18/22, No-4/22	Group 2 Baseline WF: Yes-19/23, No-5/23
Group 1: Manual WF: Yes-9/25, No-16/25	Group 2 Tech-Mediated WF: Yes-11/24, No-13/24
CS-AF Process Subjective Question 4: 50 participants (25 matched pairs, 2 surveys each) *Do you feel there is an opportunity to enhance the information quality of the BP exam workflow?*	
Group 1: Baseline WF: Yes-17/23, No-6/23	Group 2 Baseline WF: Yes-16/23, No-7/23
Group 1: Manual WF: Yes-7/25, No-18/25	Group 2 Tech-Mediated WF: Yes-14/25, No-9/23

Some participants were interested in seeing their BP data with a reference to standard reference points specific to their age band and even associated with other users on the app (anonymously). Comments included: "Share population statistics. Effectiveness of specific treatments" (T55.59.5M). "An additional graph can be added showing the heart rate measurements. The graph of the readings should be made bigger, possibly landscape on the screen, so that it is easier to see the differences in the readings. The vertical scale should be adjustable so the patient can set the axis on the graph as they want it for viewing" (T45.54.5M).

Designing a functional solution for the BP exam workflow and delivering a solution that delights users with an enhanced collaborative experience requires multiple design iterations and refinements based on real-time feedback from lead users. The analysis indicates the complex subtilties associated with delivering telehealth solution with high-quality relevant information that users trust is easy to understand and are satisfied with. The technology-mediated workflow enhanced the information quality and relevance slightly, yet there is much more opportunity for improvement in this specific area of the workflow for the future.

5.7.4. CS-AF Workflow Analysis: Section 3: TECHNOLOGY

The CS-AF Technology section incorporates survey data designed to evaluate the technology adoption of the participants in the workflows tested. Two key constructs from TAM [22] were incorporated and analyzed to uncover participant perspectives related to technology adoption: (1) Perceived Usefulness (PU) – enhanced performance and, (2) Perceived Ease of Use (PEU) – freedom from effort. The objective for this section is to determine whether participants feel that the technology-mediated workflow introduced to them delivers a more "useful" and "easier to use" solution. Additionally, the Lund USE Model [26] was integrated into the CS-AF, which includes similar PU and PEU survey questions as the TAM, with the addition of two other determinants, Satisfaction, and Ease-of-Learning. Group mean data collected from the USE Model questions was analyzed, and the results are presented in a 4-facet radar chart.

The analysis will test the hypothesis that technology-mediated workflows are perceived to be more useful, easy to use, more satisfying, and easy to learn, when compared with baseline blood pressure exam workflow. Technology adoption participant data combined from TAM and USE was analyzed to obtain a more comprehensive evaluation of the collaborative experience. Repeat measures analysis of variance *r*ANOVA between groups and within groups for Perceived Usefulness and Perceived Ease of Use are summarized below.

<table>
<tr><th colspan="3">CS-AF Evaluation Metrics and H1 Secondary Hypothesis</th></tr>
<tr><th colspan="3">Technology: Perceived Usefulness (PU)</th></tr>
<tr><td colspan="3">H1.4: Perceived Usefulness Hypothesis: It is hypothesized that technology-mediated workflows are perceived to be more useful, when compared with baseline current-state workflows.</td></tr>
<tr><td rowspan="2">Perceived Usefulness</td><td colspan="2">Qualitative evaluation of how "useful" the technology is in reference to each step in the workflow (TAM, Davis, 1989)</td></tr>
<tr><td>Determinant/Dependent Variables</td><td>Measure</td></tr>
<tr><td rowspan="2">Qualitative Questions</td><td>How <u>Useful</u>?</td><td>7-point Likert Scale (1-very useless – 7-very useful)</td></tr>
<tr><td>Opportunity to Improve <u>Usefulness</u>?</td><td>7-point Likert Scale (1-very unlikely – 7-very likely)</td></tr>
<tr><td rowspan="2">Independent Variables</td><td>Group 1 Baseline WF</td><td>Group 1 Manual WF</td></tr>
<tr><td>Group 2 Baseline WF</td><td>Group 2 Technology-Mediated WF</td></tr>
<tr><td colspan="3">Analysis: rANOVA variance analysis and analysis of group means between: Group 1 Baseline vs. Group 1 Manual Workflow and Group 2 Baseline vs. Group 2 Technology WF, and Group 1 Manual WF vs. Group 2 Tech WF. Matched Pairs t-Test was conducted for all rANOVA's that generated p-values <= .05.</td></tr>
</table>

Initial rANOVA analysis was conducted to assess the perceived usefulness (PU) at each workflow stage for all workflows within and between groups. The rANOVA analysis indicated no significant difference in mean values between Group 1 and Group 2, and within Group 2. This data represents minimal change in participants' perspectives of perceived usefulness between the baseline and the technology-mediated workflows. The only significant difference in mean values revealed through the rANOVA analysis was within Group 1, between the baseline and manual workflows, evidenced with a p-value of 0.000.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**	**StdDev**	**p-value**
Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.081
Group 2 Baseline WF	Group Mean	3.248	1.280	
Group 2 Tech WF	Group Mean	3.056	1.113	
Group 1 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.000
Group 1 Baseline WF	Group Mean	3.952	1.356	
Group 1 Manual WF	Group Mean	3.120	0.798	
Group 1 vs. Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.596

Table 28: rANOVA analysis of Perceived Usefulness (PU) by Workflow Stage, Bondy 2020

The rANOVA analysis revealed no significance between the baseline and technology mediated workflow regarding perceived usefulness, thus proving the null hypothesis value and the hypothesis false that the tech-mediated workflow would be perceived more useful, compared with the baseline workflow.

	CS-AF Technology Hypothesis H1.4	**Results**
H_0 Null Hypothesis ц BLWF = ц TMWF	The technology-mediated workflows are not perceived to be more useful, when compared with baseline workflow.	Valid
H_a Alternative Hypothesis ц BLWF != ц TMWF	The technology-mediated workflows are perceived to be more useful, when compared with baseline workflow.	False

These results are somewhat surprising, considering that the integration of the Omron BP device with the Wise&Well smartphone app delivers real-time utility with accurate blood pressure readings immediately to participants, including data visualizations in a graph for daily, weekly, and monthly comparisons. This data is, however, consistent with the theme that, from participants' perspective, there is a large gap between base functionality and a "useful" technology that is well adopted. rANOVA analysis indicated a significant variance within Group 1; further analysis using matched pairs t-test was conducted to pinpoint the specific stage in the workflow where perceived usefulness varied for Group 1 and Group 2.

The matched pairs t-test analysis for Group 1 indicates that participants felt perceived usefulness improved significantly for Stages 1, 4, and 5 of the workflow, and the only stage that PU did not improve was for Stage 3, the actual BP exam. This is understandable since this stage is the step of the workflow that is most like the traditional (in a doctor's office) BP exam and requires more effort associated with a self-exam. Group 1 participants recognized the utility and convenience of being able to conduct BP exams on their own, eliminating the need to coordinate pre-visit, registration, and post-visit activities. Group 2 participants also recognized improvement in perceived usefulness in all workflow stages, except for workflow Stage 3 (BP exam); yet the difference in mean values were not as significant. This can account for additional factors associated with technology adoption (such as behavioral intent, attitude, switching cost, etc.) which will be discussed in other sections and in the Summary section.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**		**StdDev**		**p-value**
		BL-WF	**M/T-WF**	**BL-WF**	**M/T-WF**	
Group 1 Baseline WF vs. Group 1 Man. WF	1. Pre-Visit	3.160	4.440	1.519	1.710	0.017
	2. Registration	3.840	4.600	1.675	1.555	0.127
	3. BP Exam	2.600	2.360	1.384	1.777	0.632
	4. Treatment	2.760	3.920	1.480	1.706	0.009
	5. Post-Exam	2.040	3.760	0.978	1.985	0.000
Group 2 Baseline WF vs. Group 2 Tech. WF	1. Pre-Visit	3.600	3.720	1.323	1.696	0.772
	2. Registration	3.400	3.680	1.384	1.626	0.518
	3. BP Exam	2.840	2.200	1.143	1.708	0.054
	4. Treatment	2.680	3.160	1.282	1.434	0.294
	5. Post-Exam	3.000	3.400	1.384	1.080	0.233

Table 29: Matched Pairs t-test analysis of Perceived Usefulness (PU) by Workflow Stage, Bondy 2020

The CS-AF also included a survey question to further evaluate whether participants felt technology could be used to improve perceived usefulness at each stage in the workflow for all groups. The rANOVA analysis indicated there was significant difference in mean values between groups and within both groups. The p-value for Group 1 difference was 0.000, and Group 2 difference p-value was 0.048, and the between groups p-value was 0.000, indicating that further analysis using matched pairs *t*-test is needed in order to understand the specific difference in mean values at the workflow stage.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**	**StdDev**	**p-value**
Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.048
Group 2 Baseline WF	Group Mean	2.856	1.512	
Group 2 Tech WF	Group Mean	3.456	1.716	
Group 1 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.000
Group 1 Baseline WF	Group Mean	-1.392	2.289	
Group 1 Manual WF	Group Mean	3.512	1.192	
Group 1 vs. Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.000

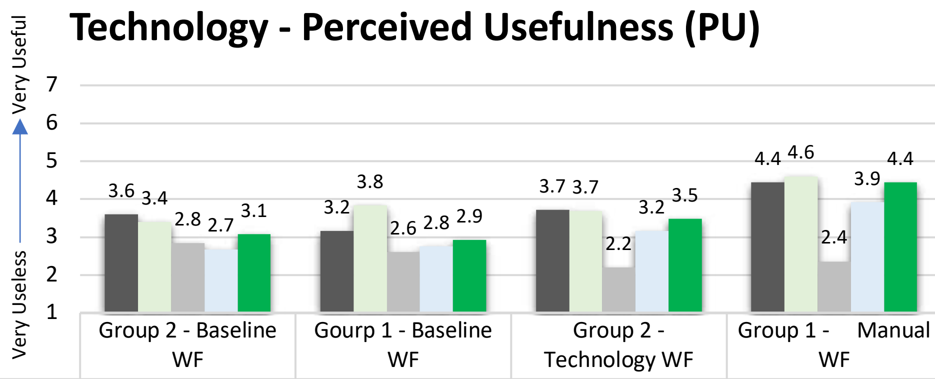
Table 30: rANOVA analysis, Can Technology Enhance Perceived Usefulness? (PU), Bondy 2020

The matched pairs *t*-test was conducted within groups for the fives stage of the blood pressure exam workflow. In is interesting to note that both groups showed an increase in the perception that technology could improve the workflow for all stages, except for Stage 3, the BP exam itself. This is consistent with the analysis for perceived usefulness, indicating that the actual activity of conducting a self-exam requires more effort and concentration by participants vs. the same activity being done by a practitioner for the baseline workflow. Group 1 participants indicated a significant difference in mean values for Stages 1, 4, and 5 indicating that these stages present an opportunity for optimization using technology. Similarly, analysis of Group 2 participants showed some degree of positive movement (although not as significant as Group 1 showed) towards the belief that technology could be improved in all workflow stages, except for Stage 3.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**		**StdDev**		**p-value**
		BL-WF	**M/T-WF**	**BL-WF**	**M/T-WF**	
Group 1 Baseline WF vs. Group 1 Man. WF	1. Pre-Visit	3.160	4.440	1.519	1.710	0.017
	2. Registration	3.840	4.600	1.675	1.555	0.127
	3. BP Exam	2.600	2.360	1.384	1.777	0.632
	4. Treatment	2.760	3.920	1.480	1.706	0.009
	5. Post-Exam	1.040	3.760	0.978	1.985	0.000
Group 2 Baseline WF vs. Group 2 Tech. WF	1. Pre-Visit	3.600	3.720	1.323	1.696	0.772
	2. Registration	3.400	3.680	1.384	1.626	0.518
	3. BP Exam	2.840	2.200	1.143	1.708	0.054
	4. Treatment	2.680	3.160	1.282	1.434	0.294
	5. Post-Exam	3.000	3.400	1.384	1.080	0.233

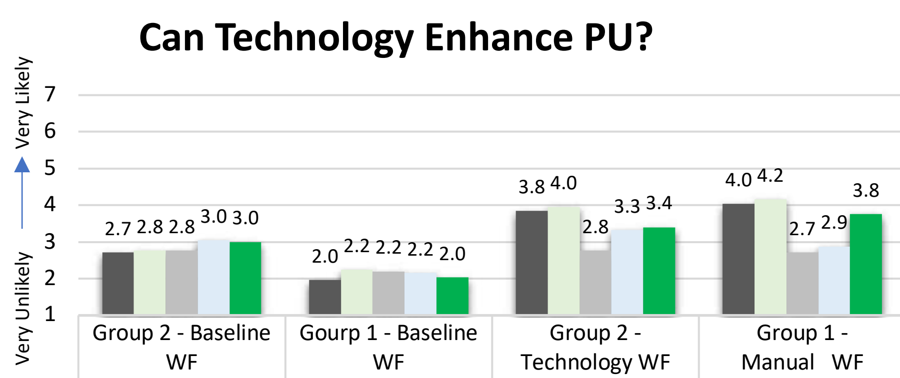
Table 31: Matched pairs t-test, Can Technology Enhance Perceived Usefulness?, Bondy 2020

The CS-AF did identify subtle differences in mean values between the baseline workflow and enhanced workflows for both Groups, respectively. A specific notable difference in mean values was identified for Stage 3 of the blood pressure exam workflow, where positive ratings for Perceived Usefulness actually declined for both Group 1 and Group 2 (manual and technology enabled workflows) from their respective baselines. This indicates that, not only was hypothesis H1.4 false, but Usefulness of the actual blood pressure exam (workflow Stage 3) was perceived to have actually declined from the baseline workflow, while all other four stages of the workflow were perceived to been improved at some degree. It should also be noted that respondents believed that technology-enhancements would be “slightly-likely” to improve Perceived Usefulness.



	Group 2 - Baseline WF	Gourp 1 - Baseline WF	Group 2 - Technology WF	Group 1 - Manual WF
1. Pre-Visit	3.6	3.16	3.72	4.44
2. Registration	3.4	3.84	3.68	4.6
3. BP Exam	2.84	2.6	2.2	2.36
4. Treatment	2.68	2.76	3.16	3.92
5. Post-Visit	3.08	2.92	3.48	4.44

Figure 52: Perceived Usefulness Group Means by Workflow Stages, Bondy 2020



	Group 2 - Baseline WF	Gourp 1 - Baseline WF	Group 2 - Technology WF	Group 1 - Manual WF
1. Pre-Visit	2.72	1.96	3.84	4.04
2. Registration	2.76	2.24	3.96	4.16
3. BP Exam	2.76	2.2	2.76	2.72
4. Treatment	3.04	2.16	3.32	2.88
5. Post-Visit	3	2.04	3.4	3.76

Figure 53: Can Technology Enhance PU? – Group Means, Bondy 2020

Similar to the analysis above for perceived usefulness, rANOVA analysis between and within Groups 1 and 2 was performed for Perceived Ease-of-Use (PEU) and technology's ability to enhance PEU.

CS-AF Evaluation Metrics and H1 Secondary Hypothesis		
Technology: Perceived Ease-of-Use (PEU)		
H1.5: Perceived Ease-of-Use Hypothesis: It is hypothesized that technology-mediated workflows are perceived to be easier to use, when compared with current-state baseline workflows.		
Ease-of-Use	Qualitative evaluation of how "easy-to-use" the technology is in reference to each step in the workflow (TAM, Davis, 1989)	
	Determinant/Dependent Variables	Measure
Qualitative Questions	Easy-to-Use?	7-point Likert Scale (1-very difficult-to-use – 7-very easy-to-use)
	Opportunity to Improve Ease-of-Use?	7-point Likert Scale (1-very unlikely – 7-very likely)
Independent Variables	Group 1 Baseline WF	Group 1 Manual WF
	Group 2 Baseline WF	Group 2 Technology-Mediated WF
Analysis: *r*ANOVA variance analysis and analysis of group means between: Group 1 Baseline vs. Group 1 Manual Workflow and Group 2 Baseline vs. Group 2 Technology WF, and Group 1 Manual WF vs. Group 2 Tech WF. Matched Pairs t-Test was conducted for all *r*ANOVA's that generated *p*-values <= .05.		

Initial rANOVA analysis was conducted to assess Perceived Ease of Use (PEU) at each workflow stage for all workflows within and between groups. The objective for this section was to determine whether participants felt that the alternate workflows evaluated deliver a solution that is "easier to use" (freedom from effort) than the baseline workflows deliver. The rANOVA analysis indicated no significant difference in mean values between Group 1 and Group 2, yet did indicate significance within both Group 1 (p-value=0.000) and Group 2 (p-value 0.006).

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**	**StdDev**	**p-value**
Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.006
Group 2 Baseline WF	Group Mean	3.152	0.899	
Group 2 Tech WF	Group Mean	2.992	1.258	
Group 1 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.000
Group 1 Baseline WF	Group Mean	2.696	0.961	

Group 1 Manual WF	Group Mean	2.800	0.970	
Group 1 vs. Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.167

Table 32: rANOVA analysis of Perceived Ease of Use (PEU) by Workflow Stage, Bondy 2020

Matched pairs *t*-test analysis was conducted for all groups to determine the specific difference in mean values at the stage-level within both groups are in favor of hypothesis H1.5. Both Group 1 and Group 2 data indicated a significant variance for Stage 3 in a negative sense, meaning that perceived ease of use actually declined for the BP exam stage in the both alternative workflows. Group 1 (p-value=.001) decreased from 2.84 to 1.60, and Group 2 (p-value=.012) decreased from 3.24 to 2.24 for stage 3. Similar to the results and analysis for PU, this indicates that participants felt perceived ease of use was more difficult for Stage 3 than when having BP readings taken in a doctor's office by a clinician. The analysis from both group participants shows that perceived ease of use for all other stages increased to some degree (except for stage 1 for Group 2, which showed an insignificant decrease.) As previously mentioned in the PU section, this reaction by participants is understandable, since Stage 3 is the step in the workflow that requires the unique effort associated of a self-exam. Amongst having other concerns with self-care for this particular stage, participants expressed concerns regarding the proper positioning of the wrist and bicep cuff for the BP exam. Additional factors associated with technology adoption (such as behavioral intent, attitude, switching cost, etc.) will be discussed in the Summary section.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**		**StdDev**		**p-value**
		BL-WF	**M/T-WF**	**BL-WF**	**M/T-WF**	
Group 1 Baseline WF vs. Group 1 Man. WF	1. Pre-Visit	2.480	3.000	1.085	1.323	0.108
	2. Registration	2.600	3.280	1.190	1.208	0.077
	3. BP Exam	2.840	1.600	1.248	1.000	0.001
	4. Treatment	2.840	3.080	1.248	1.222	0.513
	5. Post-Exam	2.720	3.040	1.173	1.241	0.425
	1. Pre-Visit	3.120	2.960	1.092	1.485	0.647

Group 2 Baseline WF vs. Group 2 Tech. WF	2. Registration	2.960	3.000	1.172	1.472	0.914
	3. BP Exam	3.240	2.240	1.200	1.715	0.012
	4. Treatment	3.240	3.320	1.200	1.626	0.855
	5. Post-Exam	3.200	3.440	1.155	1.325	0.513

Table 33: Matched pairs t-test analysis of Perceived Ease of Use (PEU) by Workflow Stage, Bondy 2020

The rANOVA analysis revealed significant difference in mean values between the baseline and technology mediated workflow regarding perceived ease of use, and further pair t-test analysis indicated that the difference in mean values was in a negative direction for workflow Stage 3. Even though there was some positive movement in most all other workflow stages, none of the increases were significant enough to provide the hypothesis; therefore, the null hypothesis is valid and the hypothesis that the tech-mediated workflow would be perceived easier to use compared with the baseline workflow is false.

	CS-AF Technology Hypothesis H1.5	Results
H_0 Null Hypothesis ɥBLWF = ɥTMWF	The technology-mediated workflows are not perceived to be easier to use, when compared with baseline workflow.	Valid
H_a Alternative Hypothesis ɥBLWF != ɥTMWF	The technology-mediated workflows are perceived to be easier to use when compared with baseline workflow.	False

These results are not that surprising considering the newness of the technology-mediated workflow, compared to the baseline for participants. Participants in the older age bands had fundamental difficulties with the base technologies in the solution, such as Bluetooth pairing, using the Omron BP device, and the basic app functionality. This data is, however, consistent with the theme that there is a considerable barrier to adoption associated with switch cost and the ability to completely understand and use a new technology. The technology learning gap was most apparent for some elderly participants that needed help with email setup and Bluetooth configuration.

The CS-AF also included a survey question to further evaluate whether participants felt technology could be used to improve perceived ease of use at each stage in the workflow for all groups. The rANOVA analysis indicated there was significant difference in mean values with groups, but not between both groups. The p-value for Group 1 difference was 0.017, the Group 2 difference p-value was 0.000, and the between-groups p-value was 0.115, indicating that further analysis using matched pairs t-test is needed in order to understand the specific difference in mean values at the workflow stage.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**	**StdDev**	**p-value**
Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.000
Group 2 Baseline WF	Group Mean	2.832	1.357	
Group 2 Tech WF	Group Mean	3.328	0.986	
Group 1 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.017
Group 1 Baseline WF	Group Mean	2.184	0.933	
Group 1 Manual WF	Group Mean	3.048	1.560	
Group 1 vs. Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.115

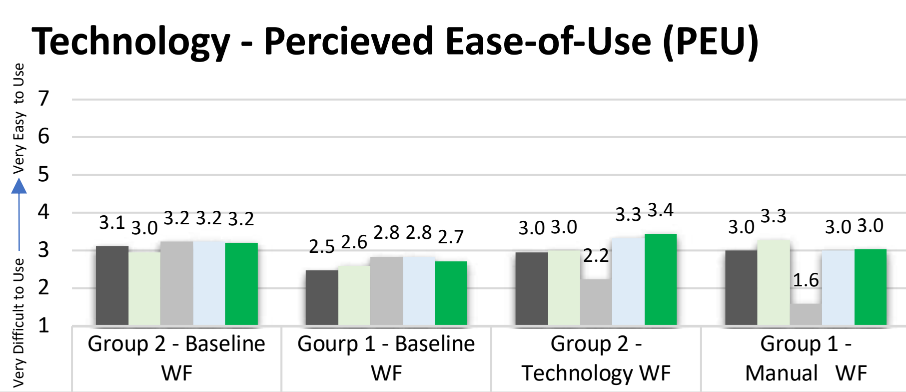
Table 34: rANOVA analysis, Can Technology Enhance Perceived Ease of Use (PEU)?, Bondy 2020

The matched pairs *t*-test was conducted within groups for the five stages of the blood pressure exam workflow. Group 1 showed an increase in the perception that technology could improve the ease of use for all stages to some degree. The data show a significant increase for Stages 1, 2, and 4, indicating the belief of participants that technology could improve ease of use. Group 2 participants also felt that technology could improve ease of use significantly for Stages 1 and 2, but to a lesser degree for Stage 5. Group 2 showed only a minor decrease in the belief that technology could improve ease of use for Stages 3 and 4. Participants expressed opportunities for the technology to be used to enhance easier communications with the doctor's office for scheduled appointments and visit check-in as a potential enhancement for Stage 1 and 2 of the technology-mediated solution (Wise&Well).

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**		**StdDev**		**p-value**
		BL-WF	**M/T-WF**	**BL-WF**	**M/T-WF**	
Group 1 Baseline WF vs. Group 1 Man. WF	1. Pre-Visit	2.200	3.440	1.155	1.660	0.004
	2. Registration	2.240	3.400	1.128	1.607	0.004
	3. BP Exam	2.080	2.360	1.187	1.777	0.510
	4. Treatment	2.080	3.040	1.187	1.837	0.031
	5. Post-Exam	2.320	3.000	1.314	1.708	0.121
Group 2 Baseline WF vs. Group 2 Tech. WF	1. Pre-Visit	2.600	3.920	1.500	1.801	0.022
	2. Registration	2.690	3.960	1.492	1.767	0.022
	3. BP Exam	2.840	$\boxed{2.440}$	1.573	1.387	0.307
	4. Treatment	3.080	3.000	1.552	1.354	0.845
	5. Post-Exam	2.960	3.320	1.457	1.180	0.288

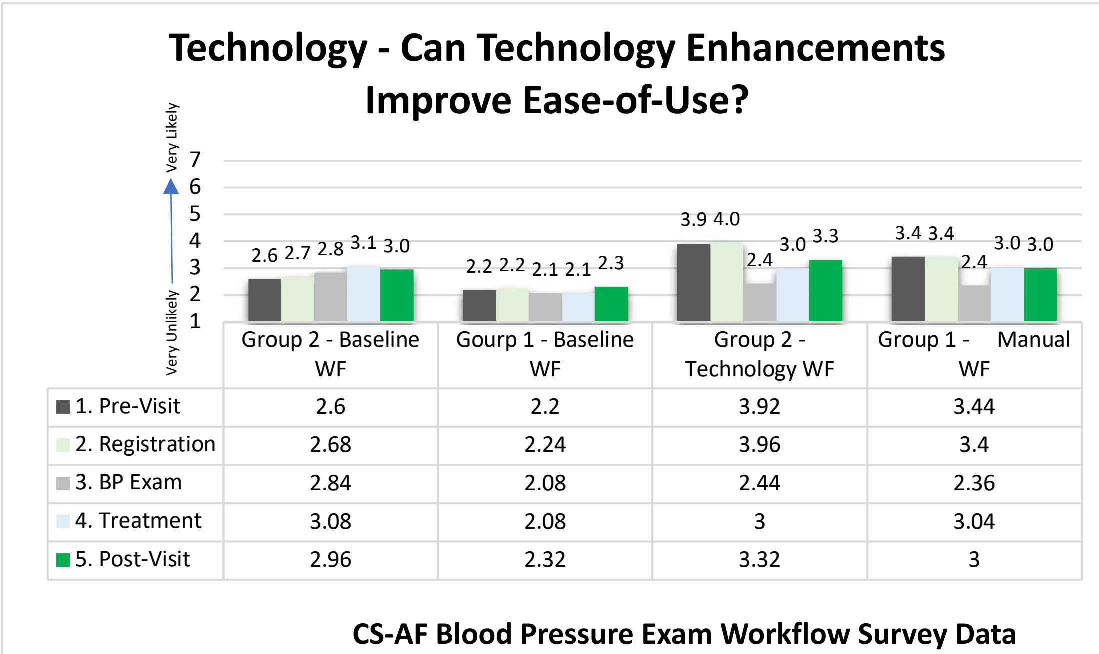
Table 35: Matched pairs t-test analysis, Can Technology Enhance Perceived Ease of Use (PEU)?, Bondy 2020

The hypothesis H1.5 proved false for ease of use; however, the CS-AF did identify significant difference in mean values within groups from the baseline, compared with the respective alternate workflows. The data confirms that participants feel there is opportunity for technology improvements to improve ease of use in the workflow, specifically surrounding the workflow Stages 1 and 2 preceding the actual BP exam.



	Group 2 - Baseline WF	Gourp 1 - Baseline WF	Group 2 - Technology WF	Group 1 - Manual WF
1. Pre-Visit	3.12	2.48	2.96	3
2. Registration	2.96	2.6	3	3.28
3. BP Exam	3.24	2.84	2.24	1.6
4. Treatment	3.24	2.84	3.32	3
5. Post-Visit	3.2	2.72	3.44	3.04

Figure 54: Ease of Use Group Means by Workflow Stages, Bondy 2020



	Group 2 - Baseline WF	Gourp 1 - Baseline WF	Group 2 - Technology WF	Group 1 - Manual WF
1. Pre-Visit	2.6	2.2	3.92	3.44
2. Registration	2.68	2.24	3.96	3.4
3. BP Exam	2.84	2.08	2.44	2.36
4. Treatment	3.08	2.08	3	3.04
5. Post-Visit	2.96	2.32	3.32	3

Figure 55: Can Technology Enhance PEU? – Group Means, Bondy 2020

The CS-AF integrates Lund’s USE Model [26] to complement the previous technology adoption analysis with determinants’ “perceived usefulness” and “ease of use.” The objective for integrating the USE model into the CS-AF was to further validate the prior analysis using PU and PEU (TAM model), while expanding the view in the areas of “ease of learning” and “satisfaction” to obtain a more comprehensive view of the participants perspective on technology adoption. The USE model incorporates a standard 30-question survey, with each question requiring a 7-point Likert-scale response. The scoring of the USE model was conducted separately for each of the four dimensions by calculating the group mean for each of the four dimensions and mean summary data for both groups; all workflows were summarized and visualized in a 4-point radar chart, enabling a visual analysis of the mean data.

<table>
<tr><th colspan="3">CS-AF Evaluation Metrics and H1 Secondary Hypothesis</th></tr>
<tr><th colspan="3">Technology: U.S.E. Model</th></tr>
<tr><td colspan="3">H1.4 Ease-of-use, and H1.5 Usefulness are combined with H1.6 and H1.7 in the USE model. Hypothesis: It is hypothesized that technology-mediated workflows are perceived to <u>easier-to-use</u>, and more <u>useful</u> when compared with current-state baseline workflows.
H1.6: Satisfaction Hypothesis: It is hypothesized that technology-mediated workflows are perceived to be more <u>satisfying</u>, when compared with current-state workflows.
H1.7: Easy-of-Learning Hypothesis: It is hypothesized that technology-mediated workflows are <u>easier-to-learn</u>, when compared with baseline current-state workflows.</td></tr>
<tr><td rowspan="2">System Usability Scale – USE</td><td colspan="2">The System Usability Scale (USE) questions compare; Perceived Usefulness, Satisfaction, Ease of Use, and Ease of Learning (Lund 2001). “Each is a positive statement (e.g., "I thought the system was easy to use"), user rates level of agreement on a seven-point Likert scale (The results of this analysis are presented using a four-quadrant radar chart).</td></tr>
<tr><td>Determinant/Dependent Variable</td><td>Measure</td></tr>
<tr><td rowspan="4">Qualitative Questions</td><td>Ease-of-Use,</td><td rowspan="4">7-point Likert Scale (1-strongly disagree – 7-strongly agree)</td></tr>
<tr><td>Perceived Usefulness</td></tr>
<tr><td>Satisfaction</td></tr>
<tr><td>Ease-of-Learning</td></tr>
<tr><td rowspan="2">Independent Variables</td><td>Group 1 Baseline WF</td><td>Group 1 Manual WF</td></tr>
<tr><td>Group 2 Baseline WF</td><td>Group 2 Technology-Mediated WF</td></tr>
<tr><td colspan="3">Analysis: Analysis of group means between: Group 1 Baseline WF, Group 1 Manual WF, Group 2 Baseline WF, and Group 2 Technology WF, are presented in a 7-point radar chart for each determinant for all groups.</td></tr>
</table>

Summary USE model data analysis corroborates similar findings as the previous perceived usefulness and ease of use data reported above.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**N**	**Mean**	**StDev**
Group 1Baseline WF	Q1-Q7 Usefulness	7	3.7143	0.2006
Group 1 Manual WF	Q1-Q7 Usefulness	7	2.029	0.333
Group 2 Baseline WF	Q1-Q7 Usefulness	7	3.606	0.427
Group 2 Tech-Mediated WF	Q1-Q7 Usefulness	7	2.491	0.355

Figure 56: USE Model (Lund): CS-AF Group Means: **Usefulness**, Bondy, 2020

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**N**	**Mean**	**StDev**
Group 1Baseline WF	Q1-Q11 Ease-of-Use	11	3.215	1.401
Group 1 Manual WF	Q1-Q11 Ease-of-Use	11	1.942	0.717
Group 2 Baseline WF	Q1-Q11 Ease-of-Use	11	3.858	0.429
Group 2 Tech-Mediated WF	Q1-Q11 Ease-of-Use	11	2.724	0.505

Figure 57: USE Model (Lund): CS-AF Group Means: **Ease of Use**, Bondy, 2020

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**N**	**Mean**	**StDev**
Group 1Baseline WF	Q1-Q4 Ease-of-Learning	4	3.170	0.247
Group 1 Manual WF	Q1-Q4 Ease-of-Learning	4	1.2600	0.0516
Group 2 Baseline WF	Q1-Q4 Ease-of-Learning	4	3.4000	0.1600
Group 2 Tech-Mediated WF	Q1-Q4 Ease-of-Learning	4	2.100	0.232

Figure 58: USE Model (Lund): CS-AF Group Means: **Ease of Learning**, Bondy, 2020

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**N**	**Mean**	**StDev**
Group 1 Baseline WF	Q1-Q7 Satisfaction	7	2.269	0.542
Group 1 Manual WF	Q1-Q7 Satisfaction	7	4.0571	0.1741
Group 2 Baseline WF	Q1-Q7 Satisfaction	7	4.183	0.343
Group 2 Tech-Mediated WF	Q1-Q7 Satisfaction	7	2.777	0.390

Figure 59: USE Model (Lund): CS-AF Group Means: **Satisfaction**, Bondy, 2020

A slight positive movement occurred in all four areas of the USE model, with the most pronounced change exhibited between Group 1 baseline WF and Group 1 Manual WF for "satisfaction" (GP1B 1.3 to GP1M 2.3). Positive movement from both Group 1 and Group 2 baseline workflows and their respective Manual and Technology-Mediated workflows was negligible, indicating that, although participants indicated some positive movement, the alternative workflows did not breakthrough with the populations as highly useful, easy to use, easy to learn, or satisfying. Opportunities abound for technological improvements focused on them being easier to use and easier to learn, and developing more useful solutions that might enhance the overall satisfaction of users.

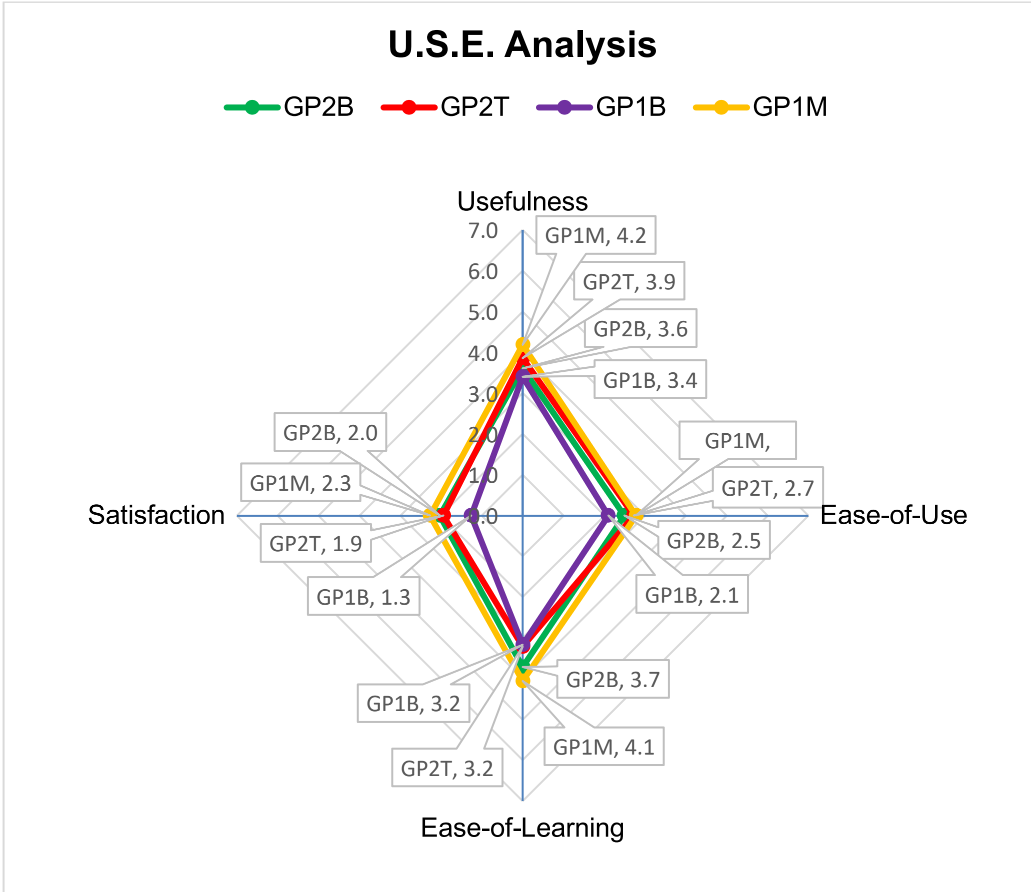


Figure 60: USE Model, Perceived Usefulness, Ease of Use, Ease of Learning, Satisfaction, Bondy 2020

	CS-AF Process Hypothesis H1.4-H1.7	Results
H_0 Null Hypothesis μ BLWF = μ TMWF	**H1.4 Ease-of-use**, **H1.5 Usefulness,** combined with **H1.6 Satisfaction** and, **H1.7 Ease-of-Learning** (USE model). Technology-mediated workflows will not be perceived to be easier-to-use, more useful, increase satisfaction, and be easier to learn when compared with current-state baseline workflows.	Valid
H_a Alternative Hypothesis μ BLWF != μ TMWF	Technology-mediated workflows will be perceived to be easier-to-use, more useful, increase satisfaction, and be easier to learn when compared with current-state baseline workflows.	False

Subjective questions were integrated into the CS-AF in efforts to complement survey data with narrative responses that are closely associated with each particular section. The table below describes the two questions presented to participants for the Technology section of the

CS-AF. The same two questions were presented to all Group 1 and 2 participants in reference to both workflows (GP1, GP2 Baseline and GP1 Manual and GP2 Technology workflows).

Participant responses to the two Technology section subjective questions are summarized below for each group and each workflow.

Technology – Subjective Question 1:

CS-AF Process Subjective Question 1: 50 participants (25 matched pairs, 2 surveys each) *Is there a particular step in the BP exam workflow that seemed difficult?*	
Group 1: Baseline WF: Yes-13/21, No-8/21	Group 2 Baseline WF: Yes 9/21, No-12/21
Group 1: Manual WF: Yes-4/25, No-21/25	Group 2 Tech-Mediated WF: Yes 10/23, No-13/23

Participants stated that they felt there were opportunities to optimize the workflow with technology, which they felt was inefficient and outdated. Several respondents stated that the pre-visit and registration stages of the workflow could be streamlined using technology. The following quotes seem to encapsulate the themes from Group 1 regarding the baseline workflow: *"*...all non-clinical aspects of the workflow are decades out of date and unnecessarily time consuming" (W35.44.2M). "I think the entire process for blood pressure checks can be done much simpler and easier" (WT35.44.10M).

Participants from Group 2 Baseline workflow echoed a similar assessment of the baseline BP exam workflow, stating that the pre-visit and registration stages of the workflow could be streamlined using technology. "All form is filled out on paper and then the data is manually entered by the receptionist" (T18.24.6M). "I think registration and first contact in exam room could be shorter or streamlined" (T45.54.8F).

Participants from Group 1 Manual workflow had very few comments. Out of two responses, one stated that the workflow was straight forward, with no areas of difficulty; the other response commented on "the manual logging of data. If data could be pushed directly to a source…" (W25.34.2M). These comments characterized a difficultly that has been eliminated with the Technology-mediated workflow used by Group 2.

Participants from Group 2 Technology-Mediated workflow (7 out of the 10 participants that responded) stated that the initial installation and setup of the Wise&Well app and configuring the app with the Omron Bluetooth device was difficult, yet once the setup was completed, there was no more difficulty. "Once the app was set -up, the workflow piece worked well" (T60.8F). There were also several participants that experienced difficulty and anxiety with the bicep cuff connection using the Omron BP monitor. "If the cuff and motor are deemed part of the technology, significantly. The awkwardness of tightening the cuff, the cuff never felt 'right' on the arm, the ramp up of the motor and corresponding squeeze proved intimidating to me. The more the ramp up, the higher my internal stress/anxiety became" (T60.5M).

Technology – Subjective Question 2:

Technology Subjective Question 2: 50 participants (25 matched pairs, 2 surveys each) *Do you believe that this BP exam workflow is effective for you to accomplish your wellness goals?*	
Group 1: Baseline WF: Yes 9/21, 12/21 No	Group 2 Baseline WF: Yes 10/24, 14/24 No
Group 1: Manual WF: Yes 23/25, 2/25 No	Group 2 Tech-Mediated WF: Yes 20/25, 5/25 No

Out of the nine participants that responded to this question for Group 1, no one responded positively concerning the current-state BP exam workflow. Respondents stated that BP exams are not frequent enough, nor are they comprehensive; most believed that they could conduct readings with better results at home, especially if the data was connected with their doctor. "I think it would be easier for me to be able to check my BP myself and give results to the doctor; this would help me avoid having to make an appointment, go to the office, wait, see the doctor, etc. It would be more helpful to send my results electronically and then use the visit to see the doctor and get treatment" (W35.44.4F). "No...(1) the data collection is insufficient to fully characterize my BP behavior broadly, (2) my PCP does not have the knowledge or interest in digging below the standard measurements and assessments" (W60.2M).

Most all of the 11 participants that responded for Group 2 stated that the baseline BP exam workflow was not effective for accomplishing their wellness goals. The respondents felt that the BP exams were too infrequent and somewhat of a routine process, and not very connected with overall wellness. "No, they only do one measurement and try and make a decision. It took years for my Dr to decide to put me on a low-level blood pressure medication. There is not a constant monitoring. I'm not even sure if I still need to be on the medication" (T45.54.5M). "Not effective. The whole process is long and needs to be pre-planned. Regular BP measurement and shortened lag-time will be more effective for my goals" (T55.59.5M).

Out of the 16 participants that responded, all of the response were positive, stating that the manual BP exam workflow as effective and promoted better overall understanding of their BP data and its relationship to other health variables in their life. The manual BP exam workflow was viewed as straight-forward and effective. "Yes, being able to use a BP cuff at home and with easy access will help me accomplish my wellness goals with ease" (W18.24.4F). "Yes, very easy to use and provided additional information (pattern) to have more in-depth conversations with my doctor" (W35.44.3F). "Yes...It allows me to have a simple understanding of how my blood pressure and pulse react to certain situations. Like after having a drink or exercising (W45.54.1M). "Yes, I can do it as part of my daily routine and I plan to continue to record my BP on a daily basis (W55.59.2M).

Only 2 out of the 16 participants that responded had a negative response to the technology-mediated BP exam workflow. One participant felt that more interaction with the Dr. would be necessary for them to better trust the BP readings, and the other negative response was related to the Omron bicep cuff itself and anxiety associated with the tightening of the cuff during the BP exam. The other 14 respondents felt that the technology-mediated workflow was effective and worked to help accomplish their wellness goals. *"I do feel like it was effective for me because I was a lot more active because I wanted to keep my blood pressure good (T18.24.8F). "Yes. It's enlightening to see a record over a day week of what my BP is. And it helps install the importance of regularly measuring one's BP" (T35.44.5M). "The BP measurement is ideal for this because it is a simple quick measurement that needs to be done at least once a week to get trends, but it is almost not worth hours of time going to the office to have it done by a nurse. If I had months of measurements, I would not have any stress about them measuring my BP in the office at any given time" (T45.54.5M). "I like being able to take bp...I think it is interesting that doctor can access readings, but sometimes it was difficult to record them with phone (connection, trying to connect while arm in machine, etc.)" (T55.59.7F).*

5.7.5. CS-AF Workflow Analysis: Section 4: ATTITUDE & BEHAVIOR

The "Attitude & Behavior" section of the CS-AF includes data analysis of survey questions from the TAM [22] construct, including participants' "attitude towards using" and their "behavioral intent to use" the workflow. CS-AF also incorporates the Net Promoter Score™ (NPS) [27] to further analyze the attitude and behavior of participants willingness to promote the workflow.

The goal of the Attitude and Behavior section is to uncover participants feelings toward adoption of the workflows evaluated. Understanding whether participants have a positive attitude toward using the workflow, and if they intend to use the workflow, is key to technology adoption. Are the participants motivated to use the workflow provided? Do they have the intention to use, or to avoid, the workflow? Ajzen defines behavior “as an observable act, is related to the individual’s persuasive or attitudinal feelings; whereas attitude/attitudinal feelings are defined as the degree to which a person has favorable or unfavorable evaluation or appraisal of the behavior in question” [66:188]. When attitude and behavior are positive toward a new technology-mediated workflow, adoption is more likely.

This section will help to determine participants’ attitude and behavior toward the workflow with an understanding of the propensity that they have towards promoting or recommending the workflow to people they are close to in their community (friend and family). The TAM’s determinates for attitude and behavior and the NPS’s promotability question were incorporated into the CS-AF with the goal of gaining a deeper understanding of the emotional and psychological aspects of participant adoption.

<table>
<tr><th colspan="3">CS-AF Evaluation Metrics and H1 Secondary Hypothesis</th></tr>
<tr><th colspan="3">Attitude and Behavior</th></tr>
<tr><td colspan="3">H1.9: Attitude-Toward-Use Hypothesis: It is hypothesized that the <u>attitude to use</u> the technology-mediated workflows is more positive, when compared with baseline workflow.</td></tr>
<tr><td rowspan="2">Attitude</td><td colspan="2">Quantitative comparison of users’ attitude toward using the technology incorporated in the workflow (TAM, Davis, 1989).</td></tr>
<tr><td>Determinant/Dependent Variables</td><td>Measure</td></tr>
<tr><td rowspan="3">Qualitative Questions</td><td>Positive Opinion about the WF?</td><td>7-point Likert Scale (1-strongly disagree – 7-strongly agree)</td></tr>
<tr><td>Using the WF is good for me?</td><td>7-point Likert Scale (1-strongly disagree – 7-strongly agree)</td></tr>
<tr><td>The WF is appropriate form me?</td><td>7-point Likert Scale (1-strongly disagree – 7-strongly agree)</td></tr>
<tr><td rowspan="2">Independent Variables</td><td>Group 1 Baseline WF</td><td>Group 1 Manual WF</td></tr>
<tr><td>Group 2 Baseline WF</td><td>Group 2 Technology-Mediated WF</td></tr>
<tr><td>Analysis</td><td colspan="2">rANOVA variance analysis and analysis of group means between: Group 1 Baseline vs. Group 1 Manual Workflow and Group 2 Baseline vs. Group 2 Technology WF, and Group 1 Manual WF vs. Group 2 Tech WF. Matched Pairs t-Test was conducted for all rANOVA’s that generated p-values <= .05.</td></tr>
</table>

Initial rANOVA analysis was conducted in order to assess participants attitude to use the workflows using TAM determinants within and between groups. The objective for this section was to determine participants' attitude toward using the alternate workflows, compared with the baseline BP exam workflows. The rANOVA analysis indicated significant difference in mean values within Group 1 (p-value=0.000) and Group 2 (p-value=0.001), yet did not indicate significance between Groups 1 and 2 (p-value=0.400). This rANOVA analysis suggests that further insights are necessary at the determinate level in order to better understand the difference in mean values as it relates to the Attitude hypothesis H1.9.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**	**StdDev**	**p-value**
Group 2 Difference rANOVA	1. Positive, 2. Good for Me, 3. Appropriate, 4. Valuable, 5. Modern			0.001
Group 2 Baseline WF	Group Mean	3.256	1.732	
Group 2 Tech WF	Group Mean	2.240	1.328	
Group 1 Difference rANOVA	1. Positive, 2. Good for Me, 3. Appropriate, 4. Valuable, 5. Modern			0.000
Group 1 Baseline WF	Group Mean	2.744	1.778	
Group 1 Manual WF	Group Mean	1.672	0.914	
Group 1 vs. Group 2 Difference rANOVA	1. Positive, 2. Good for Me, 3. Appropriate, 4. Valuable, 5. Modern			0.400

Table 36: rANOVA analysis, CS-AF Attitude to Use, Bondy 2020

Matched pairs t-test analysis was conducted for each determinant within Group 1 and 2 to determine the specific difference in mean values at the determinate level in support of hypothesis H1.9. Both Group 1 and Group 2 data analysis indicate a decrease in all attitude determinates across both workflows, with significant decrease in determinants 1, 3, and 5 for Group 1, and determinants 1, 4, and 5 for Group 2.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**		**StdDev**		**p-value**
		BL-WF	**M/T-WF**	**BL-WF**	**M/T-WF**	
Group 1 Baseline WF vs. Group 1 Man. WF	1. Positive	3.240	1.680	1.899	0.945	0.001
	2. Good for Me	1.680	1.480	0.748	0.823	0.346
	3. Appropriate	2.680	1.680	1.701	0.852	0.015
	4. Valuable	2.400	1.600	1.528	0.816	0.018
	5. Modern	3.720	1.920	2.092	1.115	0.000
Group 2 Baseline WF vs. Group 2 Tech. WF	1. Positive	3.320	2.160	1.626	1.214	0.004
	2. Good for Me	2.400	1.800	1.384	1.155	0.061
	3. Appropriate	3.360	2.600	1.578	1.633	0.100
	4. Valuable	3.200	2.400	1.915	1.472	0.050
	5. Modern	4.000	1.848	2.240	1.052	0.000

Table 37: Matched pairs t-text analysis, CS-AF Attitude to Use, Bondy 2020

Both groups expressed a decrease in their positive attitude toward the workflow evaluated. Group 1 significantly decreased their attitude toward using the manual workflow with respect to their "positive" feeling toward using (1), whether the workflow is "appropriate" for them (3), and whether the workflow was "modern" (5). Group 2 reported similar decrease in their attitude toward using with respect to their "positive" feeling toward using (1), whether the workflow is "valuable for them (4), and whether the workflow was "modern" (5). These results resoundingly prove the hypothesis false; participants' attitude towards using the alternate workflows, across the board in both workflows, decreased when compared with baseline current-state BP workflow.

	CS-AF Attitude Hypothesis H1.9	**Results**
H_0 Null Hypothesis ɥBLWF = ɥTMWF	The attitude toward using the technology-mediated workflow is not more positive, when compared with baseline workflow.	Valid
H_a Alternative Hypothesis ɥBLWF != ɥTMWF	The attitude toward using the technology-mediated workflow is more positive, when compared with baseline workflow.	False

The results are somewhat puzzling as many participants expressed that they were "satisfied with how they accomplished the BP exam" using the alternate workflows during the subjective questions. For both Group 1 and Group 2, 21 out of the 23 participants that responded to the subjective question stated that they were satisfied with how they accomplished the manual and technology-mediated workflows, respectively. The data identifies the very subtle and sensitive area of attitude and behavior associated with technology adoption. It seems that participants can be "satisfied" with the workflow, while not being fully emotionally attached to the workflow at a level that shifts their "attitude to use" the workflow in the positive direction. Further analysis on these findings will be discussed in the Summary Analysis section.

Similar to the analysis of the attitude questions derived from the TAM, an analysis of Behavioral questions aimed to better understand participants' "intention to use" the workflows was conducted. Specifically, questions across six determinates were analyzed, including, (1) Intend to Use, (2) Increase use of BP Exams, (3) Easy to Use, (4) Enjoy Using, (5) Good for your Health, and (6) Family believes it is good for your health.

<table>
<tr><th colspan="3">CS-AF Evaluation Metrics and H1 Secondary Hypothesis</th></tr>
<tr><th colspan="3">Attitude and Behavior</th></tr>
<tr><td colspan="3">H1.10: Behavioral Intention Hypothesis: It is hypothesized that the behavioral intention to use technology-mediated workflows is more positive, when compared with baseline current-state workflows.</td></tr>
<tr><td rowspan="2">Behavioral Intent</td><td colspan="2">Quantitative comparison of users' behavioral intent toward using the technology incorporated in the workflow (TAM, Davis, 1989).</td></tr>
<tr><td>Determinant</td><td>Measure</td></tr>
<tr><td rowspan="2">Qualitative Questions</td><td>I intend to use the WF?</td><td>7-point Likert Scale (1-strongly disagree – 7-strongly agree)</td></tr>
<tr><td>I expect my use of the WF will continue?</td><td>7-point Likert Scale (1-strongly disagree – 7-strongly agree)</td></tr>
<tr><td rowspan="2">Independent Variables</td><td>Group 1 Baseline WF</td><td>Group 1 Manual WF</td></tr>
<tr><td>Group 2 Baseline WF</td><td>Group 2 Technology-Mediated WF</td></tr>
<tr><td>Analysis</td><td colspan="2">rANOVA variance analysis and analysis of group means between: Group 1 Baseline vs. Group 1 Manual Workflow and Group 2 Baseline vs. Group 2 Technology WF, and Group 1 Manual WF vs. Group 2 Tech WF. Matched Pairs t-Test was conducted for all rANOVA's that generated p-values <= .05.</td></tr>
</table>

Initial rANOVA analysis was conducted to assess participants behavioral intent to use the workflows using TAM determinants within and between groups. The objective for this section was to determine participants' behavioral intent toward using the alternate workflows, compared with the baseline BP exam workflows. The rANOVA analysis indicated significant difference in mean values within Group 1 (p-value=0.000) and Group 2 (p-value=0.001), yet did not indicate significance between Groups 1 and 2 (p-value=0.223). This rANOVA analysis suggests that further insights are necessary at the determinate level to better understand the difference in mean values as it relates to the Behavior hypothesis H1.10.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**	**StdDev**	**p-value**
Group 2 Difference rANOVA	1. Intend to Use, 2. Increase BP Exams, 3. Easy to Use, 4. Enjoy Using, 5. Good for Health, 6. Family believes good for health			0.001
Group 2 Baseline WF	Group Mean	3.560	1.720	
Group 2 Tech WF	Group Mean	2.320	1.348	
Group 1 Difference rANOVA	1. Intend to Use, 2. Increase BP Exams, 3. Easy to Use, 4. Enjoy Using, 5. Good for Health, 6. Family believes good for health			0.000
Group 1 Baseline WF	Group Mean	3.013	1.757	
Group 1 Manual WF	Group Mean	1.933	1.103	
Group 1 vs. Group 2 Difference rANOVA	1. Intend to Use, 2. Increase BP Exams, 3. Easy to Use, 4. Enjoy Using, 5. Good for Health, 6. Family believes good for health			0.223

Table 38: rANOVA analysis, CS-AF Behavioral Intent, Bondy 2020

Matched pairs *t*-test analysis was conducted for each determinant within Group 1 and 2 to determine the specific difference in mean values at the determinate level in support of hypothesis H1.10. Both Group 1 and Group 2 data analysis indicate a decrease in all behavior determinates across both workflows with significant decrease in determinants 1, 3, and 4 for Group 1, and in determinants 2, 3, and 4 for Group 2.

Both groups expressed an overall decrease in their behavioral intent toward using the workflows evaluated. Group 1 significantly decreased their behavioral intent to use the manual workflow with respect to determinants (1) Intend to Use, (3) Easy to Use, and (4) Enjoy Using. Group 2 reported similar decrease in behavioral intent to use for determinants (2) Increase use of BP Exams, (3) Easy to Use, and (4) Enjoy Using. These results resoundingly prove the hypothesis false; participants' behavior towards using the alternate workflows, across the board in both workflows ,decreased when compared with the baseline current-state BP workflow.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**		**StdDev**		**p-value**
		BL-WF	**M/T-WF**	**BL-WF**	**M/T-WF**	
Group 1 Baseline WF vs. Group 1 Man. WF	1. Intend to Use	3.160	2.000	2.014	1.118	0.023
	2. Increase BP Exams	3.000	2.280	1.732	1.339	0.151
	3. Easy to Use	3.240	1.520	1.508	0.872	0.000
	4. Enjoy Using	4.120	2.160	1.943	1.028	0.001
	5. Good for my Health	2.280	1.640	1.400	0.810	0.061
	6. Family believes it is good for my health	2.280	2.000	1.275	1.258	0.430
Group 2 Baseline WF vs. Group 2 Tech. WF	1. Intend to Use	3.600	2.600	2.062	1.500	0.091
	2. Increase BP Exams	3.920	2.000	1.801	0.913	0.000
	3. Easy to Use	3.840	1.920	1.573	0.997	0.000
	4. Enjoy Using	4.120	2.560	1.394	1.583	0.000
	5. Good for my Health	2.840	2.240	1.675	1.422	0.206
	6. Family believes it is good for my health	3.040	2.600	1.513	1.472	0.273

Table 39: Matched pairs t-text analysis, CS-AF Behavioral Intent, Bondy 2020

Similar to the Attitude section, the Behavioral results are somewhat puzzling, as many participants expressed that they were "satisfied with how they accomplished the BP exam" using the alternate workflows during the subjective questions. The data identifies the very subtle and sensitive area of attitude and behavior associated with technology adoption. It seems that participants can be "satisfied" with the workflow, while indicating that from a behavioral perspective they are not completely invested in the solutions at a level that would cause them to commit to use emotionally. Further analysis on these findings will be discussed in the Summary Analysis section.

	CS-AF Behavior Hypothesis H1.10	**Results**
H_0 Null Hypothesis μBLWF = μTMWF	The attitude toward using the technology-mediated workflow is not more positive, when compared with baseline workflow.	Valid
H_a Alternative Hypothesis μBLWF != μTMWF	The attitude toward using the technology-mediated workflow is more positive, when compared with baseline workflow.	False

The final component of the CS-AF Attitude and Behavior sections is an analysis of the participants' feelings toward the promotability of the workflow evaluated. CS-AF also incorporates the Net Promoter Score™ (NPS) [11] to further analyze the attitude and behavior of participants willingness to promote the workflow.

<table>
<tr><th colspan="3">CS-AF Evaluation Metrics and H1 Secondary Hypothesis</th></tr>
<tr><th colspan="3">Attitude and Behavior</th></tr>
<tr><td colspan="3">H1.8: Promotability Hypothesis: It is hypothesized that technology-mediated workflows are more highly promoted, when compared with baseline current-state workflows.</td></tr>
<tr><td rowspan="2">Net Promoter Score (NPS)</td><td colspan="2">Quantitative comparison of users' likelihood of promoting (recommending) the product/workflow to a friend or colleague (Reichheld, 2003).</td></tr>
<tr><td>Determinant/Dependent Variables</td><td>Measure</td></tr>
<tr><td>Qualitative Questions</td><td>How likely is it that you would recommend this WF to a friend?</td><td>Scale of 0 to 10 (0 being "Not at all likely" and 10 being "extremely likely).</td></tr>
<tr><td rowspan="2">Independent Variables</td><td>Group 1 Baseline WF</td><td>Group 1 Manual WF</td></tr>
<tr><td>Group 2 Baseline WF</td><td>Group 2 Technology-Mediated WF</td></tr>
<tr><td>Subjective Questions</td><td colspan="2">Do you feel satisfied with how you accomplished your task? elaborate?
Did any part of this workflow frustrate you? elaborate?</td></tr>
</table>

Participants rate the likelihood of promoting the workflow evaluated on a scale of 0-not at all likely to 10-extremely likely. Participants scoring from 9 to 10 are considered to be Promoters, users who will "keep using and refer the workflow to others" [27]. Those scoring from 7 to 8 are considered Passives who are “vulnerable to competitors or other alternative workflows”. Those scoring 0 to 6 are considered Detractors who are “unhappy customers that can damage a brand or perception of the workflow through word-of-mouth”. The percentage of Promoters minus the percentage of Detractors will return the Net Promoter Score™ (NPS) [27].

Initial matched pairs *t*-test reveal a significant variance within groups and for the Net Promoter Score. The matched pairs t-test results indicate that the variance between the baseline workflows both groups was significantly different than the alternative workflows evaluated, and the difference between the groups was also significant in support of a valid hypothesis H1.8 regarding the promotability of the alternative workflows.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**	**StdDev**	**p-value**
How Likely is it that you would recommend this workflow to a friend or colleague? (scale 1- 10)				
Group 2 Baseline WF	NPS Determinants	5.440	2.859	0.000
Group 2 Tech WF	NPS Determinants	7.360	2.215	
Group 2 Difference		2.040	2.525	
Group 1 Baseline WF	NPS Determinants	5.440	2.859	0.001
Group 1 Manual WF	NPS Determinants	7.760	2.241	
Group 1 Difference		2.320	2.911	

Table 40: Matched pairs t-test between and within Groups for CS-AF Promotability (NPS), Bondy 2020

Analysis of the NPS data for each group and their respective workflows identified similar results regarding promotability for both Group 1 and 2 baseline workflows, indicating consistency across the population regarding the baseline BP exam workflow. Participants at large felt that the baseline BP exam workflow was not very promotable (-48% and -44% for Groups 1 and 2, respectively.) The groups also had a similar percentage of Promoters (GP1 and GP2: 16%), Passive

(GP1: 20% vs. GP2: 24%), and Detractors (GP1: 64% vs. GP2: 60%). Both Group 1 and Group 2 exhibited a positive move in the promotional direction for their respective alternative workflows, with Group advancing from NPS from -48% to 32% for the manual BP exam workflow, and Group 2 advancing the NPS score from -44% to -4%.

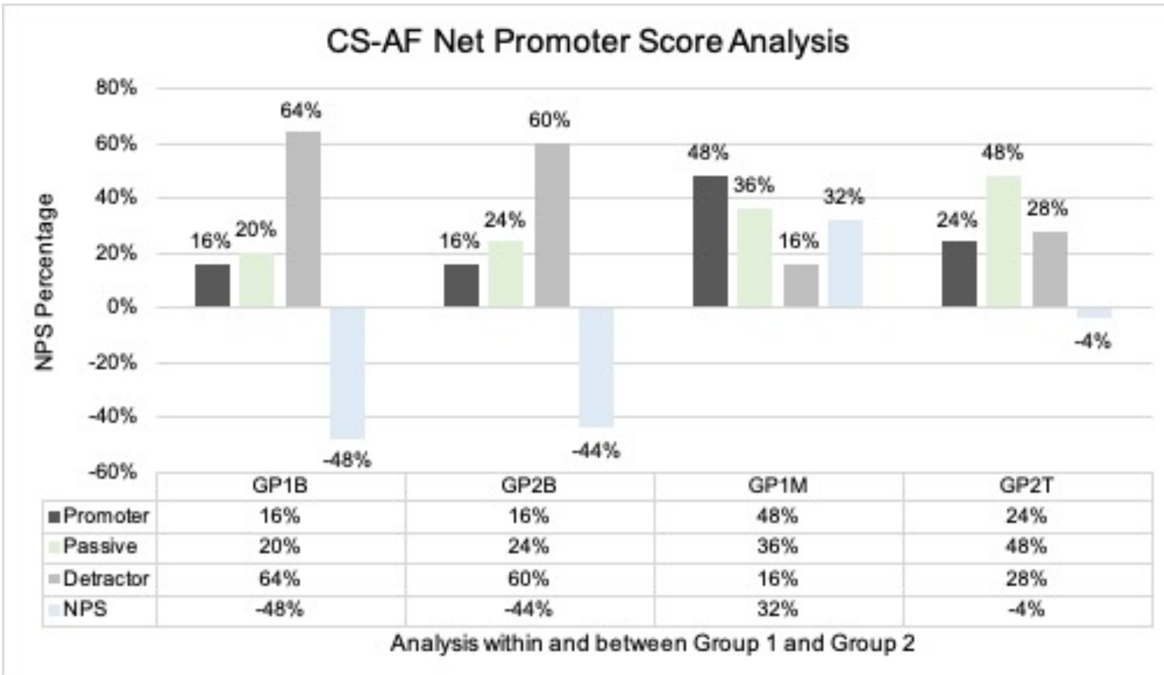


Figure 61: CS-AF Net Promoter Analysis within and between Groups, Bondy 2020

The promotability analysis validates the hypothesis H1.8 that the technology-mediated workflow would be viewed as more positive or promotable, when compared with the baseline BP exam workflow. Overall promotability scores from the NPS analysis show a 40% increase for Group 2 workflow comparison. Group 1 data shows an even more dramatic increase in the promotability score, with an increase in NPS of 80% from the baseline BP exam workflow to the manual BP exam workflow.

	CS-AF Promotability Hypothesis H1.8	Results
H_0 Null Hypothesis ɥBLWF = ɥTMWF	The attitude toward using the technology-mediated workflow is not more positive, when compared with baseline workflow.	False
H_a Alternative Hypothesis ɥBLWF != ɥTMWF	The attitude toward using the technology-mediated workflow is more positive, when compared with baseline workflow.	Valid

Even with the NPS increases and a valid alternative hypothesis, there is still a large opportunity to increase promotability with Group 1 at 32% and Group 2 at -4%. The data does, however, support the hypothesis as well as earlier findings in Attitude and Behavior. This indicates that, even though participants feel positive about the workflow, there is a large gap between a trend in the positive direction and participants becoming emotionally connected to a new workflow at a level where they are advocates or evangelists for the new technology-mediated workflows.

The CS-AF also has incorporated a number of subjective qualitative questions with the aim of collecting an expanded assessment of the user's perspective towards the workflows evaluated. The following summary information reflects themes that have been extracted from the analysis of participants' subjective feedback to related questions regarding attitude and behavior toward the workflow evaluated.

Attitude and Behavior – Subjective Question 1:

CS-AF Attitude and Behavior Subjective Question 1: 50 participants (25 matched pairs, 2 surveys each) *Do you feel satisfied with how you accomplished your blood pressure exam?*	
Group 1: Baseline WF: Yes -11/21, No-10/21	Group 2 Baseline WF: Yes 11/24, No-13/24
Group 1: Manual WF: Yes-21/23, No-2/23	Group 2 Tech-Mediated WF: Yes 21/23, No-2/23

For the baseline BP exam workflow, both groups had mixed feelings regarding satisfaction. Approximately one-half of Group 1 participants (11/21) expressed satisfaction with the baseline BP workflow. “I am satisfied with how I accomplished my manual blood pressure exams. Instructions were clear and the device was easy to use” W18.24.4F.

Similarly, 11/24 of Group 2 participants felt satisfied with current BP exam workflow. “I'm satisfied with the BP exam. The physician has known me for years and I can ask him to explain or elaborate as needed” T60.8F. “I enjoy having the staff at the office do the exam for me” T25.34.6M. “ … it was informative and easy to use” T25.34.8F. Group 1 had 10/21 participants not satisfied with the baseline BP exam workflow.

Many stated that the process was time-consuming and too infrequent to provide meaningful information. Participants believe that the workflow was inefficient. “It is one of the most inefficient tasks I ever have to deal with. Even the DMV workflow has become more efficient than this” (W35.44.2M). Group 2 had 13/24 participants dissatisfied with the baseline workflow; “I wish I could do it myself and submit my results. I would also like to see my results over time” T18.24.5M. “There has to be a more comprehensive, holistic orientation, as opposed to just receiving a number and a prescription” T60.5M.

With regard to the alternate workflows evaluated, Group 1 and Group 2 expressed a marked improvement, with 21/23 participants expressing satisfaction for the alternative workflows introduced. Group 1 participants were interested in more efficient ways to record and store the BP data. “No. I wish it was able to create a graph of the data” W45.54.1M. Group 1 expressed satisfaction with the manual workflow, as well; “Yes I am satisfied with how I accomplished my manual blood pressure exams. instructions were clear and the device was easy to use” W18.24.4F. “Yes- I think there is a lot of potential for this technology. Make it a part of a greater automated process involving the primary care doctor using apps and telemedicine” W55.59.2M.

Two of the Group 2 participants expressed negative feedback on the technology workflow; “I am satisfied with my use of the app. I don't tend to trust the recording of private info online, so I have a hesitancy for using this type of app, but I successfully used it!” T60.8F. Most of the feedback for the tech-mediated workflow was however positive (21/23). “Overwhelmingly, yes. It felt like a chore to take the readings 4 times a day at first, but I got used to it” T35.44.5M. “Yes! My BP has never been so consistent. I will continue to take my BP morning and night. I appreciated the immediate feedback especially when it registered a little high and it told me to recheck. As I said before, I have never been so consistent about taking it” T45.54.7F.

Attitude and Behavior – Subjective Question 2:

CS-AF Attitude and Behavior Subjective Question 2: 50 participants (25 matched pairs, 2 surveys each) *Do you feel that the blood pressure exam provides information that you would not otherwise see?*	
Group 1: Baseline WF: Yes -16/23, No-7/21	Group 2 Baseline WF: Yes 13/22, No-13/22
Group 1: Manual WF: Yes-21/23, No-2/23	Group 2 Tech-Mediated WF: Yes 21/25, No-4/23

More than half of Group 1 and Group 2 participants felt that the baseline workflow provided valuable information that they might not otherwise see. There was minimal feedback from the 7/23 participants that responded negatively for Group 1, while 9/22 Group 2 participants had more negative feedback including, “No. I could use a blood pressure device myself” T18.24.5M. “No, I do take it on my own at home sometimes” T45.54.5M. “No, as my blood pressure is elevated because I am at Dr’s. office” T45.54.8F. “Because of white coat syndrome, reads are highly inaccurate or inconsistent. Oftentimes, they will take 3-6 reads and thereafter insist I still need to be on the medications” T60.5M.

With respect participants feeling that to the alternative workflows provided valuable information they might not otherwise see, both Group 1 and Group expressed an improvement in the workflows: Group 1: 21/23 yes, while Group 2: 21/25 yes.

Negative responses for Group 1 included, " … doctors have more knowledge than I do and can suggest things to do I might not even think of" W45.54.4F. Negative responses from Group 2 included, "You could basically do the same thing the app does with a notebook and pencil next to your BP machine. Being able to plot more data in different ways would add a lot of value to the tool" T35.44.6M. "It can be alarming when the reading indicates an "elevated" range. What does "elevated" really mean? Should I be concerned? What do I do?" T35.44.9M.

From the positive perspective regarding the technology-mediated workflow, Group 2 participants stated, "Yes, without the "Wise&Well app," I would not be monitoring my BP and heart rate" T35.44.7F. "Absolutely. I liked the updates to the wellness diagrams. It was easy to have them all in one place" T45.54.7F. "Yes. Having the app and Omron cuff on demand gave me info on BP that I would otherwise not have had access to unless I was at an appt. with my doctor" T55.59.6M. "yes, consistent tracking. Also, helpful during an Afib incident" T60.7F.

Both Group 1 and 2 participants expressed frustration with the baseline BP exam workflow (Group 1: 14/22, Group 2: 12/24); specifically, the most common frustration with the baseline workflow was time-related (Group 1: 10/14, Group 2: 6/12). "Long wait/lag times" W18.24.2M. "Yes, lag-time" W18.24.1M, "Communications from doctor" W45.54.2M, "Not sure the nurse practitioner pays attention to detail when doing it, just a check mark to get done. Very dependent on your setting" W55.59.1M. "Limited information collected and analyzed beyond standard expectations" W60.2M. "The waiting time after registration is particularly frustrating" T. 18.24.5M. "Significant time to complete the process. Quality of information" T55.59.5M

There was a marked improvement in the frustration level of participants with respect to Group 1 manual workflows (Group 1: 16/23 had no frustration). Most of the comments for Group 1 manual workflow were related to logging BP data and the inability to analyze their BP data. "I struggle to remember to do it" W18.24.3F, "logging BPs manually on paper" W25.34.1M. Group 2, technology-mediated workflow showed an increase in frustration (17/24) primarily associated with installation and the learning curve associated using a Bluetooth connected device. "The initial process of putting the app on my phone. The directions were difficult to follow" T35.44.7F. "Sync app with the device needed some help. Yes, receiving error messages was frustrating" T18.24.7F, "Yes, that I had to reconnect to Bluetooth every time" T25.34.7F. However, 7/24 Group 2 participants expressed no frustration; "No, I didn't, I found it very easy to use" T18.24.8F.

Attitude and Behavior – Subjective Question 3:

CS-AF Attitude and Behavior Subjective Question 3: 50 participants (25 matched pairs, 2 surveys each) *If there is something in BP exam workflow you could change, what would it be?*	
Group 1: Baseline WF: Yes -15/17, No-2/17	Group 2 Baseline WF: Yes 11/19, No-8/19
Group 1: Manual WF: Yes-8/13, No-5/13	Group 2 Tech-Mediated WF: Yes 11/21, No-10/21

The majority of responses suggesting what participants would change for the baseline workflow were, again, time-related; Group 1 expressed 15/17 would make changes and 10/17 of those suggestions were time-related. Only 11/19 for Group 2 expressed they would make changes to the baseline workflow, yet similarly to group 1, 6/11 were also associated with the reduction of time. "Reduce lag times, registration times waiting times, I would change the registration area to being a computer that I can check into rather than waiting for a secretary in line/clipboard" W18.24.4F. "The waiting before BP is checked could be reduced" T18.24.6M. "The waiting before BP is checked could be reduced" T18.24.6M.

Other suggestions included the need for more relevant information both in the form of clinician feedback, relevant content, and data visualizations regarding their historic blood pressure data. "A simple way to collect large amounts of BP information as a function of multiple relevant variables and a PCP with the knowledge and interest to interpret and share the results, comment on implications if not changed, and recommendations" W60.2M. "In depth seminars on treatment options, alternatives, holistic considerations" T60.5M, "Monitoring at work and home" T45.54.6M. "Make it easy to do myself at home and send the results to my Dr." T45.54.5M.

With respect to the alternative workflows, 8/13 Group 1 participants expressed they would make changes, and for Group 2, 11/21 would suggest workflow changes. For the manual BP workflow, most of the feedback was associated with the automated collection and reporting of BP data. "Automatically transmitting my data into my medical records, and granting access to my doctor" W35.44.2M, "Writing down the info. If the cuff could be linked somehow to my doctor's office, they could get the information immediately w/o me having to relay it verbally" W35.44.4F, "Creation of graphs" W45.54.1M, "Yes- automate the rest of the process (doctor notifications, etc.)" W55.59.2M, "Auto recording of data" W60.2M.

Group 2 participants expressed an interest in further automation of the BP device to include multiple automated reads, more flexibility in the display and customization of BP data, and a more robust/less volatile Bluetooth connectivity. "More data display options, averaging, charts, etc. When you put your "mood" in... you never see that again. Why answer that question if you never see it again?" T35.44.6M, "Change the software in the cuff so that one button push completes several measurements and saves the average" T45.54.5M. "More user-friendly interface and BT connection" T45.54.6M, "Connection issues and do not send multiple messages after readings" T55.59.7F, "I would have a doctor or PA continuously available to monitor concerns. I called Dr Grover twice, but it felt like an infringement on her personal life" T60.5M.

5.7.6. CS-AF Workflow Analysis: Section 5: OUTCOMES

The CS-AF Outcomes section incorporates survey questions focused on the awareness that participants feel other collaborative members of the workflow, such as clinicians, have towards their goals. The objective for this section is to better understand, from participants' perspectives, whether they feel clinicians involved in the workflow share a common ground with respect to with the information they need and goals they have. Are clinicians aware of their goals and is their alignment?

The survey design for the Outcomes section leverages CSCW/HCI constructs from the Activity Awareness Model [13] for awareness and goals setting. Neale et al. posit activity awareness as an overarching concept to describe a comprehensive view of collaboration from the activity perspective [13], [119]. Their research introduces the Activity Awareness Model as a conceptual framework aimed at representing the key variables that one should consider when evaluating distributive computing applications. The Activity Awareness Model highlights the need for researchers to capture and evaluate user goals using two determinants, Awareness and Goal Alignment, that are collected by users along each stage in the workflow in attempts to pinpoint target outcomes for collaborative users of the workflow [12].

Awareness refers to (1.a) how individual users of the workflow feel clinicians involved in the workflow are aware of their communications needs and (1.b.) whether information quality meets their needs. The second part of the Outcomes section includes an evaluation of goal alignment. This refers to how individual users of the workflow feel clinicians involved in the workflow share mutual common ground with respect to desired goals of the workflow. The data points of outcomes are captured using a qualitative research survey for both the baseline and alternative workflows evaluated.

CS-AF Evaluation Metrics and H1 Secondary Hypothesis		
Outcomes		
H1.11: Awareness Hypothesis: It is hypothesized that technology-mediated workflows increase the awareness of information sharing needs, when compared with baseline current-state workflows.		
Awareness	Quantitative comparison of users' perception regarding awareness of participants in the workflow related to information sharing and communications (Neale, Carroll & Rosson, 2004).	
	Determinant/Dependent Variables	Measure
Qualitative Questions	How aware do you feel clinicians are of your goals for each step in the WF?	7-point Likert Scale (1- very unaware – 7-very aware)
	How likely does the information quality meet your needs at each stage of the BP exam workflow?	7-point Likert Scale (1- very Unlikely – 7-very Likely)
Independent Variables	Group 1 Baseline WF	Group 1 Manual WF
	Group 2 Baseline WF	Group 2 Technology-Mediated WF
Analysis	*r*ANOVA variance analysis and analysis of group means between: Group 1 Baseline vs. Group 1 Manual Workflow and Group 2 Baseline vs. Group 2 Technology WF, and Group 1 Manual WF vs. Group 2 Tech WF. Matched Pairs *t*-Test was conducted for all *r*ANOVA's that generated *p*-values <= .05.	

Initial rANOVA analysis was conducted to assess how aware participants felt clinicians are with their goals for each stage of the workflows evaluated. The analysis indicated significant difference in mean values within Group 2 (p-value=0.030) and an insignificant difference in mean values within Group 1 and between Group 1 and Group 2. This rANOVA analysis suggests that further insights are necessary at the determinate level to better understand the difference in mean values at the workflow stage level as it relates to the Awareness hypothesis H1.11.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**	**StdDev**	**p-value**
Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.030
Group 2 Baseline WF	Group Mean	3.696	1.274	
Group 2 Tech WF	Group Mean	3.488	1.172	
Group 1 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.449
Group 1 Baseline WF	Group Mean	3.776	1.210	
Group 1 Manual WF	Group Mean	3.576	1.214	
Group 1 vs. Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.683

Table 41: rANOVA analysis for CS-AF Outcomes: Awareness, Bondy 2020

Matched pairs t-test analysis was conducted for each determinant within Group 1 and 2 to determine the specific difference in mean values at the determinate level for all stages in the workflow and all workflows evaluated. Negligible variances were observed for Group 1 when comparing the baseline workflow to the alternative, manual workflow. The largest difference in mean values was observed for workflow Stage 3 (the BP exam), where the awareness rating dropped .5 on a 7-point Likert scale, most likely due to the participant conducting the BP exam on their own with a manual BP device that was not connected to the clinicians in any way.

The only significant difference in mean values for the awareness question came from Group 2, p-value= 0.010, for stage 3 (BP Exam) where the awareness rating of participants dropped 1 point from “slightly unaware” to “unaware”. As mentioned previously for Group 1, the Group 2 participants felt clinicians were less aware of them during the BP exam stage since they were “on their own administering self-care” when conducting the actual BP exam. It is interesting to note that Group 2 participants understood that the clinician involved in the study had a real-time view of their BP readings, yet they scored their feeling of clinicians’ awareness as lower than the manual workflow that was completely disconnected.

Groups/Workflows (Independent Variables)	Determinants (Dependent Variables)	Mean		StdDev		p-value
		BL-WF	M/T-WF	BL-WF	M/T-WF	
Group 1 Baseline WF vs. Group 1 Man. WF	1. Pre-Visit	4.040	4.040	1.620	1.541	1.000
	2. Registration	4.400	3.960	1.633	1.541	0.252
	3. BP Exam	3.520	3.000	1.584	1.414	0.163
	4. Treatment	3.120	3.200	1.333	1.500	0.834
	5. Post-Exam	3.800	3.680	1.414	1.600	0.768
Group 2 Baseline WF vs. Group 2 Tech. WF	1. Pre-Visit	4.280	4.160	1.720	1.650	0.786
	2. Registration	4.600	4.280	1.472	1.595	0.469
	3. BP Exam	3.760	2.760	1.615	1.665	0.010
	4. Treatment	2.600	2.920	1.443	1.412	0.175
	5. Post-Exam	3.250	3.250	1.452	1.225	1.000

Table 42: Matched pairs t-test analysis for CS-AF Outcomes: Awareness, Bondy 2020

The second part of the awareness evaluation included a question that pertains to the common ground shared between the participant and the clinician in the workflow. How likely does the information quality for each stage in the workflow meet your needs? Initial rANOVA analysis indicated no significant difference in mean values within Groups or between Groups for this question. Further analysis was conducted to try to determine any notable movement regarding participants' awareness feelings at each stage in the workflows evaluated.

Groups/Workflows (Independent Variables)	Determinants (Dependent Variables)	Mean	StdDev	p-value
Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.362
Group 2 Baseline WF	Group Mean	3.448	1.217	
Group 2 Tech WF	Group Mean	3.088	1.179	
Group 1 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.441
Group 1 Baseline WF	Group Mean	3.480	1.277	
Group 1 Manual WF	Group Mean	3.336	1.227	
Group 1 vs. Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.850

Table 43: rANOVA analysis for CS-AF Outcomes: Information Quality, Bondy 2020

Matched pairs t-test analysis was conducted for each workflow stage within Group 1 and 2 to determine whether there were notable differences in mean values at any stages in the workflows evaluated. For Group 1, the only stages in the workflow that exhibited a very slight positive move in information quality awareness were Stages 4 and 5 (Treatment, Post-Exam); all other stages declined with respect to the manual vs. the baseline workflow. This can account for the participants being isolated with only the self-care BP exam option and no real iteration with clinicians on the Treatment or Post-Exam steps. With respect to Group 2, every stage of the workflow declined slightly with respect to participants' awareness of information quality, except for a very slight increase under Stage 4 (Treatment). These results are not significant enough to prove the hypothesis valid. However, the fact that participants from Group 1 scored similarly to participants from Group 2 indicates that the technology-mediated workflow offered participants a more connected technology, yet was not perceived as an increase in the collaborative connection between participants and clinicians. This data suggests that a more concerted effort is needed to facilitate improvements in the connectedness between clinicians and participants.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**		**StdDev**		**p-value**
		BL-WF	**M/T-WF**	**BL-WF**	**M/T-WF**	
Group 1 Baseline WF vs. Group 1 Man. WF	1. Pre-Visit	3.800	3.680	1.658	1.492	0.733
	2. Registration	4.200	3.760	1.756	1.422	0.283
	3. BP Exam	3.000	2.600	1.472	1.472	0.317
	4. Treatment	3.080	3.200	1.579	1.555	0.740
	5. Post-Exam	3.320	3.440	1.376	1.502	0.677
Group 2 Baseline WF vs. Group 2 Tech. WF	1. Pre-Visit	3.760	3.400	1.422	1.708	0.400
	2. Registration	3.920	3.440	1.498	1.685	0.242
	3. BP Exam	3.440	2.760	1.609	1.332	0.104
	4. Treatment	2.720	2.800	1.514	1.500	0.759
	5. Post-Exam	3.400	3.040	1.500	1.241	0.295

Table 44: Matched pairs t-test analysis for CS-AF Outcomes: Information Quality, Bondy 2020

Both the Awareness and Information Quality analysis proved the hypothesis H1.11 false, the technology-mediated workflow did not increase the awareness or information communication needs, when compared with baseline BP exam workflow. Similar feelings were expressed in the Attitude & Behavior sections, indicating that participants need more feedback from clinicians to feel they have common ground with clinicians; simply having access to the BP data is not enough to impact participants' feeling toward awareness. More analysis was conducted through the subjective questions for this section to uncover further insight and themes from participants.

	CS-AF Awareness Hypothesis H1.11	Results
H_0 Null Hypothesis μBLWF = μTMWF	The technology-mediated workflow will not increase the awareness of information sharing needs, when compared with baseline current-state workflows.	Valid
H_a Alternative Hypothesis μBLWF != μTMWF	The technology-mediated workflow will increase the awareness of information sharing needs, when compared with baseline current-state workflows.	False

The second aspect of the CS-AF Outcomes section includes a specific question to determine how aligned participants felt clinicians were with their specific goals at each step in the workflow for the workflows evaluated.

CS-AF Evaluation Metrics and H1 Secondary Hypothesis Outcomes		
H1.12: Goal Alignment Hypothesis: It is hypothesized that technology-mediated workflow increases goal alignment, when compared with baseline current-state workflows.		
Goal Alignment	Quantitative comparison of users' perception regarding goal alignment with participants in the workflow (Neale, Carroll & Rosson, 2004).	
	Determinant/Dependent Variables	Measure
Qualitative Questions	How aligned do you feel clinicians are with your goals for each step in the WF?	7-point Likert Scale (1- very misaligned – 7-very aligned)
Independent Variables	Group 1 Baseline WF	Group 1 Manual WF
	Group 2 Baseline WF	Group 2 Technology-Mediated WF
Analysis	*r*ANOVA variance analysis and analysis of group means between:	

CS-AF Evaluation Metrics and H1 Secondary Hypothesis	
Outcomes	
	Group 1 Baseline vs. Group 1 Manual Workflow and Group 2 Baseline vs. Group 2 Technology WF, and Group 1 Manual WF vs. Group 2 Tech WF. Matched Pairs *t*-Test was conducted for all *r*ANOVA's that generated *p*-values <= .05.
Subjective Questions	What was your primary goal for this workflow? Did you have any sub-goals for this workflow? elaborate?

Initial rANOVA analysis was conducted to assess the goal alignment that participants felt towards clinicians for each stage of the workflows evaluated. The analysis indicated significant difference in mean values within Group 1 (p-value=0.006) and an insignificant difference in mean values within Group 2 and between Group 1 and Group 2. This rANOVA analysis suggests that further insights are necessary at the determinate level to better understand the difference in mean values at the workflow stage level as it relates to the Awareness hypothesis H1.12.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**	**StdDev**	**p-value**
Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.381
Group 2 Baseline WF	Group Mean	3.224	1.049	
Group 2 Tech WF	Group Mean	3.312	1.407	
Group 1 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.006
Group 1 Baseline WF	Group Mean	3.560	1.134	
Group 1 Manual WF	Group Mean	3.304	1.262	
Group 1 vs. Group 2 Difference rANOVA	1. Pre-Visit, 2. Registration, 3. BP Exam, 4. Treatment, 5. Post-Exam			0.364

Table 45: rANOVA analysis, CS-AF Goal Alignment, Bondy 2020

Matched pairs t-test analysis was conducted for each determinant within Group 1 and 2 to determine the specific difference in mean values for all stages in the workflow that were evaluated. Significant difference in mean values was identified for Group 1: Stage 2 (Registration) p-value=0.024, with a reduction from neutral to slightly misaligned, and Group

2, Stage 4 (Treatment), p=0.053, indicating an almost significant variance in the treatment stage 4, from misaligned to slightly misaligned. None of these difference in mean values are significant enough to prove the Hypothesis valid and further underscore the very minimal movement that occurred in the Outcomes section across the board between all the workflow evaluated.

Groups/Workflows (Independent Variables)	**Determinants** (Dependent Variables)	**Mean**		**StdDev**		**p-value**
		BL-WF	**M/T-WF**	**BL-WF**	**M/T-WF**	
Group 1 Baseline WF vs. Group 1 Man. WF	1. Pre-Visit	3.960	3.440	1.594	1.193	0.131
	2. Registration	4.440	3.560	1.635	1.356	0.024
	3. BP Exam	3.120	2.680	1.481	1.520	0.257
	4. Treatment	2.800	3.320	1.443	1.574	0.188
	5. Post-Exam	3.480	3.520	1.610	1.531	0.898
Group 2 Baseline WF vs. Group 2 Tech. WF	1. Pre-Visit	3.600	3.760	1.384	1.786	0.746
	2. Registration	3.840	3.760	1.434	1.589	0.853
	3. BP Exam	3.040	2.840	1.670	1.700	0.503
	4. Treatment	2.560	3.000	1.294	1.658	0.053
	5. Post-Exam	3.080	3.200	1.320	1.384	0.671

Table 46: Matched pairs t-test analysis, CS-AF Goal Alignment, Bondy 2020

The goal alignment analysis proved hypothesis H1.12 to be false, since the technology-mediated workflow did not significantly increase participants' goal alignment when compared with baseline BP exam workflow. Group 1 manual workflow showed a reduction in goal alignment, from the baseline, for every stage of the workflow with a significant difference in mean values for Stage 2 (Registration). Group 2, tech-mediated workflow, reported a slight improvement in Stages 1 and 4, and a significant improvement in Stage 5; only Stages 2 and 3 had a slight decline for Group 2.

None of the positive movement in goal alignment for Group 2 was significant enough to claim advancement for the goal alignment perspective with participants. Similar feelings were expressed in the Attitude & Behavior sections, indicating that participants need more iterative feedback from clinicians to feel they have established common ground with clinicians; simply having access to the BP data (technology) is not enough to impact participants' feelings toward shared-goals with clinicians.

	CS-AF Goal Alignment Hypothesis Description H1.12	**Results**
H_0 Null Hypothesis μBLWF = μTMWF	Technology-mediated workflow does not increase goal alignment, when compared with baseline current-state workflows.	Valid
H_a Alternative Hypothesis μBLWF != μTMWF	Technology-mediated workflow increases goal alignment, when compared with baseline current-state workflows.	False

Further analysis was conducted with subjective responses from participants to uncover overarching themes that might be derived from the evaluation associated with outcomes.

Outcomes – Subjective Question 1:

CS-AF Outcomes Subjective Question 1: 50 participants (25 matched pairs, 2 surveys each) *What are your primary goals for this blood pressure exam workflow?(yes=have goals)*	
Group 1: Baseline WF: Yes -25/25, No-0/25	Group 2 Baseline WF: Yes 24/24, No-0/24
Group 1: Manual WF: Yes-25/25, No-0/25	Group 2 Tech-Mediated WF: Yes 24/24, No-0/24

Most all participants responded that they had established goals for the blood pressure trial (Group 1: 25/25, and Group 2: 24/25). The most dominant goals recorded from the baseline workflows for Group 1 and 2 was, naturally, to monitor/track their blood pressure. Several participants stated that, not only was it a goal to record and monitor their blood pressure, they also had a goal to better understand how the blood pressure is connected to their overall health. "I would like to keep better track of my blood pressure and understand potential triggers that make it high" W35.44.3F. "Keep track of my blood pressure and determine how I should alter my lifestyle to improve it." W18.24.2M.

Other themes, such as goals for more accurate and consistency of BP readings, were also shared. "Reduce doctor visit but still get doctor correct advice" T25.34.5M. "Accurate measurement outside of a doctor's office" T35.44.5M. Many participants were motivated with the ability to conduct self-exams, remote-asynchronous at home with BP readings that could evaluate over time. "BP testing remotely and access to doctor notes" T25.34.5M. "Gather accurate long-term information about my BP that can be used to make informed treatment decisions" T45.54.5M. "To regularly monitor BP readings and make adjustments to lifestyle and/or diet to improve reading outcomes" T55.59.6M.

Participants were also asked if they had secondary goals associated with the blood pressure exam workflow trial. Both Group 1 and 2 baseline workflow participants had 17/24 responses, indicating they had secondary goals. It is interesting to note that the number of participants with secondary goals decreased from the baseline to the alternative workflow for both Group 1 (-2) and Group 2 (-7), respectively; this could be an indication that some of the secondary goals have been addressed with the alternative workflow.

Outcomes – Subjective Question 2:

CS-AF Outcomes Subjective Question 2: 50 participants (25 matched pairs, 2 surveys each) *Do you have any secondary health & wellness goal(s) you hope to achieve with this blood pressure exam workflow?*	
Group 1: Baseline WF: Yes -17/24, No-7/24	Group 2 Baseline WF: Yes 17/24, No-7/24
Group 1: Manual WF: Yes-12/19, No-7/19	Group 2 Tech-Mediated WF: Yes 10/24, No-14/24

A reoccurring secondary goal stated by participants was to lose weight, which is included in two of the six primary triggers for hypertension (exercise, weight, diet, salt, alcohol, and smoking) [173]. A variety of other secondary goals were voiced by participants from both groups. "Measurement/Reinforcement of health goals" T35.44.5M. "General touch base about health including diet, exercise and anxiety" T45.54.6M. "Keep my diabetes in check" W25.34.2M. "I would like to lose weight and lower my cholesterol." T45.54.8F. "I need to see if lifestyle changes likewise affect my BP and how soon that happens. And it's useful to see the effects of being "unhealthy" (lots of drinking on the 4th of July, for example) and how that affects my BP" T35.44.5M. "To improve exercise/stress management" T35.44.8F.

Participants were asked whether their goals for the particular workflows they were involved in have been accomplished or not. It is interesting to note that only 7/20 participants for Group 1 and 11/20 participants for Group 2 felt they had accomplished their goals for the baseline BP workflows. In contrast, there was a large increase in their goal accomplishment rating for the alternative workflow evaluated: 16/22 Group 1, and 18/23 Group 2. Even with the hypothesis being false for "perceived usefulness" (Technology section), 78.2% of the technology-mediated workflow participants stated that their goals had been accomplished with the workflow. This builds on the observation that there are degrees of technology acceptance, ranging from a cursory level where primary goals are accomplished to a secondary level where secondary goals accomplished and a deep emotional attachment is established where participants become evangelists for the solution. It is clear that the "goal achievement" needle did move with respect to the technology-mediated workflow; however, there remains much room for improvement.

Outcomes – Subjective Question 3:

CS-AF Outcomes Subjective Question 3: 50 participants (25 matched pairs, 2 surveys each) *Were all of your goals accomplished by this blood pressure exam workflow, or are there some unmet goals*?	
Group 1: Baseline WF: Yes -7/20, No-13/20	Group 2 Baseline WF: Yes 11/20, No-9/20
Group 1: Manual WF: Yes-16/22, No-6/22	Group 2 Tech-Mediated WF: Yes 18/23, No-5/23

Participants responding to the "goal accomplishment" for the baseline workflow expressed concerns. "The goals were met, but at what cost? An hour of my time. My time is as valuable as the doctors – literally" W35.44.2M. "Under the current workflow of going to the Dr.'s I often feel like I have an inaccurate view of my health as they are done in 6-month check-ins" WT35.44.10M. "Unmet goals - hard to make sure my BP is consistent if only getting checked twice a year" W45.54.3F. "Unmet: BP information quality. I would like to see BP measurement done regularly" T55.59.5M.

With respect to the alternative workflows evaluated, several Group 1 participants voiced an interest in interaction with the clinician; they like conducting BP exams at home, but felt cut off from clinicians. "What would a doctor tell me about my readings?" W55.59.1M. "Yes- except for the interaction with the doctor, of which there was none" W55.59.2M. Even Group 2 participants (with real-time connectivity to the MD) felt like more collaborative engagement with clinicians is required; this is an important theme that will be discussed in the summary section. "Accomplished, but would need to test the collaboration with real doctor" T45.54.6M. "More sharing of comparative data will help in the app" T55.59.5M.

The final subjective question was targeted specifically to Group 2 participants that used the technology-mediated solution (Wise&Well app integrated with the Omron BP monitor) in efforts to gauge the effectiveness of the solution, in comparison to the baseline workflow.

Outcomes – Question 4 (only for Group 2 Technology-Mediated Workflow

CS-AF Outcomes Subjective Question 4: 25 participants (Group 2, technology-mediated WF only) *The technology-mediated blood pressure exam workflow (Wise&Well app & Omron device) - delivers a more collaborative real-time experience with your doctor than the tradition "in-office" blood pressure workflow. (Likert-scale rating 1-7)*	
7 - Strongly Agree: 6/25 participants – 24%	3 - Slightly Disagree: 0/25 participants
6 - Agree: 11/25 participants – 44%	2 - Disagree: 0/25 participants
5 - Slightly Agree: 7/25 participants – 28%	1 - Strongly Disagree: 0/25 participants

4 - Neither Agree/Disagree: 1/25 participants – 4%	Mean:5.88, Median:6, Mode:6, StdDev: 0.8326

The survey data reveals an almost unanimous rating of the technology-mediated to be more collaborative experience than the baseline (traditional in-doctors-office) workflow, with only 1 participant being neutral, and 24 participants who slightly agreed, agreed, or strongly agreed that the alternative workflow was more collaborative that the baseline. As an isolated question, there is no statistical claim that the technology-mediated workflow has everything participants want in a BP exam workflow. It does, however, indicate that the incremental shift from in-office to remote asynchronous and connected is a positive shift. Further investigation is needed to address the specific gaps that have been identified with the CS-AF and iterative version on an enhanced experience; addressing the gaps identified in this study will be required to ensure large-scale adoption.

5.8. CS-AF Hypertension Exam Workflow Analysis Summary

One of the primary objectives for this research was to develop a framework and methodology to evaluate technology-mediated collaborative workflow. This summary analysis highlights the results of an expanded methodology to increase the precision of the CS-AF to analyze the gains and gaps associated with technology solutions, compared with a current-state (baseline) workflow and a control group with a manual BP exam workflow. The summary results associated from the hypertension workflow empirical study using the expanded CS-AF methodology to assess the adoption of a BP exam telehealth technology solution aimed at better doctor-patient collaboration follows. This summary characterizes summary data and analysis results and learnings uncovered during the field study, as well as the effectiveness of the CS-AF, as presented in the Research Questions and Hypothesis for this research.

5.8.1. CS-AF Summary Analysis

Comprehensive analysis of each of the five components of the CS-AF was conducted and reported previously in this chapter. This section will provide a summary assessment of the significant findings from each of the elements of the CS-AF, including the overarching themes derived from the data and subjective responses from participants in the study.

For any analysis framework like the CS-AF, there is a delicate balance between the detail needed to extract meaningful analysis and the need for a somewhat parsimonious approach that can be replicated. The hypertension workflow analysis includes expanded statistical analysis of all questions and metrics incorporated into the CS-AF to ensure that a complete and clear view of participants' assessment towards adoption is extracted. With this added complexity, it may be difficult to visualize a summary comparison of the baseline workflow and the alternative workflows evaluated. For this reason, the following CS-AF Summary Scorecard has been developed. The summary scorecard is designed to capture a high-level view of the status of a given workflow using the summary data presented in the specific elements of the CS-AF (CS-AF workflow specific determinants – H1 Secondary Hypothesis). It should be noted that the detail behind this CS-AF Summary Scorecard is contained in the prior sections in this chapter.

The CS-AF Summary Scorecard incorporates a summary rating of each specific workflow evaluated with summarized metrics from the CS-AF, including a color-coded visualization of the progress of each key metric toward the ultimate goal of a highly adopted solution by participants across all facets of the CS-AF, including Context, Process, Technology, Attitude and Behavior, and Outcomes. The diverse range of metrics and acceptability levels included in the CS-AF establishes a very high standard for technology-mediated collaborative workflow adoption, and the summary scorecard enables a quick visual, side-by-side comparison on all key CS-AF metrics. The goal for the scorecard is to enable an easy-to-understand snapshot of the analysis and comparison within groups of the baseline workflow and alternative workflow evaluated, and between groups comparing the results of the manual vs. the technology-mediated workflows. The following CS-AF Summary Scorecards represents the data and analysis from the BP exam workflow study. The legend describes the abbreviations and codes included in the CS-AF scorecard.

CS-AF Summary Scorecard within Group 1 follows.

CS-AF Element	WF	H1.1-H1.12 Valid/False		CS-AF Determinant	CS-AF Summary Statistics												
Context	BL			Sync	5.6	PD	1.9	#P	2.7	CP	1.9	N	1.9	PP	4.5	T	2.7
H1.1	MN	V		Async	2.6	PD	3.5	#P	1.3	CP	1.0	N	3.8	PP	3.5	T	1.6
Process	BL			Cycle-Times	1	8.60	2	4.56	3	3.88	4	9.32	5	6.08			
H1.2	MN	V		Cycle-Times	1	0.44	2	0.60	3	3.52	4	0.76	5	0.52			
	BL			CT Acceptability	1	4.68	2	4.52	3	4.72	4	3.36	5	4.44			
H1.2	MN	V		CT Acceptability	1	5.56	2	5.44	3	6.04	4	5.52	5	5.28			
	BL			Lag-Times	1	4.40	2	10.04	3	8.16	4	8.00	5	5.48			
H1.2	MN	V		Lag-Times	1	0.36	2	0.48	3	1.04	4	0.40	5	0.48			
	BL			LT Acceptability	1	4.08	2	3.16	3	4.16	4	3.88	5	4.00			
H1.2	MN	V		LT Acceptability	1	5.28	2	5.28	3	5.68	4	5.04	5	5.00			
	BL			Info-Relevance	1	3.24	2	4.12	3	2.40	4	1.80	5	2.60			
H1.3	MN		F	Info-Relevance	1	4.80	2	4.84	3	2.56	4	3.68	5	4.20			
	BL			Info-Importance	1	3.56	2	4.32	3	2.00	4	1.52	5	2.16			
H1.3	MN		F	Info-Importance	1	4.72	2	4.72	3	2.44	4	3.68	5	4.16			
Technology	BL			Usefulness	1	3.16	2	3.84	3	2.60	4	2.76	5	2.04			
H1.4	MN		F	Usefulness	1	4.44	2	4.60	3	2.36	4	3.92	5	3.76			
	BL			Tech-Improve-PU	1	3.16	2	3.84	3	2.60	4	2.76	5	1.04			
	MN			Tech-Improve-PU	1	4.44	3	4.60	3	2.36	4	3.92	5	3.76			
	BL			Ease-of-Use	1	2.48	2	2.60	3	2.84	4	2.84	5	2.72			
H1.5	MN		F	Ease-of-Use	1	3.00	3	3.28	2	1.60	4	3.08	5	3.04			
	BL			Tech-Improve-PE	1	2.20	2	2.24	3	2.08	4	2.08	5	2.32			
	MN			Tech-Improve-PE	1	3.44	2	3.44	2	2.36	4	3.04	5	3.00			
	BL			Satisfaction	2.27	Mean across WF – USE Model – 7 Determinants											
H1.6	MN		F	Satisfaction	4.06	Mean across WF – USE Model – 7 Determinants											
	BL			Ease-of-Learning	3.17	Mean across WF – USE Model – 4 Determinants											
H1.7	MN		F	Ease-of-Learning	1.26	Mean across WF – USE Model – 4 Determinants											
Att.& Behav.	BL			Attitude	1	3.24	2	1.68	3	2.68	4	2.40	5	3.70			
H1.9	MN		F	Attitude	1	1.68	2	1.48	3	1.68	4	1.60	5	1.92			
H1.10	BL			Behavior	1	3.2	2	3.0	3	3.24	4	4.12	5	2.84	6	2.3	
	MN		F	Behavior	1	2.0	2	2.28	3	1.52	4	2.16	5	1.64	6	2.0	
H1.8	BL			NPS						5.4	Detractors						
	MN	V		NPS							7.8	Passives					
Outcomes	BL			Awareness	1	4.04	2	4.44	3	3.52	4	3.12	5	3.80			
H1.11	MN		F	Awareness	1	4.04	2	3.96	3	3.00	4	3.20	5	3.68			
	BL			Info-Quality	1	3.80	2	4.20	3	3.00	4	3.08	5	3.32			
	MN			Info-Quality	1	3.68	2	3.76	3	2.60	4	3.20	5	3.44			
	BL			Goal-Alignment	1	3.96	2	4.44	3	3.12	4	2.80	5	3.48			
H1.12	MN		F	Goal-Alignment	1	3.44	2	3.56	3	2.68	4	3.32	5	3.52			

Table 47: CS-AF Summary Scorecard, Group 1 Analysis, Bondy 2020

CS-AF Summary Scorecard Legend: BL-Baseline Workflow, MN-Manual Workflow, TM-Technology-Mediated Workflow
Green: significant positive move, Yellow: minor pos. move, Red: significant neg. move.

Context	Synchronous vs. Async	Physical Distribution	# Participants	Communities of Practice	Nascence	Planned Permanence	Turnover
Process	Cycle time and Lag time are in .10 minutes for 5 workflow stages						
Technology	PU and PEU, and Technology Improvement questions are calculated for 5 workflow stages, Satisfaction and Ease of Learning are mean values across the WF (USE).						
Att.&Behv.	Attitude is assessed across the workflow for 5 determinants, Behavior is assessed across the workflow for 6 determinants						
	Net Promoter Score (NPS) is calculated as a group mean and presented on a scale from 1-10						
Outcomes	Each question in Awareness and Goal Alignment are evaluated for the 5 workflow stages						

CS-AF Summary Scorecard within Group 2 follows.

CS-AF Element	WF	H1.1-H1.12 Valid/False		CS-AF Determinant	CS-AF Summary Statistics													
Context	BL			Sync	4.6	PD	2.3	#P	2.2	CP	2.0	N	1.6	PP	4.3	T	2.6	
H1.1	TM	V		Async	1.9	PD	4.7	#P	1.6	CP	1.3	N	5.0	PP	3.8	T	2.3	
Process	BL			Cycle-Times	1	9.92	2	4.52	3	4.68	4	10.5	5	3.12				
H1.2	TM	V		Cycle-Times	1	2.28	2	1.72	3	3.22	4	3.86	5	1.72				
	BL			CT Acceptability	1	4.56	2	4.72	3	5.32	4	5.04	5	4.06				
H1.2	TM	V		CT Acceptability	1	5.80	2	5.84	3	6.00	4	5.72	5	5.60				
	BL			Lag-Times	1	4.88	2	11.6	3	7.82	4	7.68	5	4.48				
H1.2	TM	V		Lag-Times	1	.88	2	1.72	3	1.12	4	1.60	5	1.28				
	BL			LT Acceptability	1	4.08	2	3.92	3	4.08	4	3.96	5	4.60				
H1.2	TM	V		LT Acceptability	1	5.88	2	5.76	3	5.84	4	5.52	5	5.44				
	BL			Info-Relevance	1	3.44	2	3.68	3	2.16	4	1.80	5	2.80				
H1.3	TM		F	Info-Relevance	1	3.52	2	3.96	3	2.40	4	2.88	5	3.04				
	BL			Info-Importance	1	3.64	2	4.04	3	2.12	4	1.72	5	2.68				
H1.3	TM		F	Info-Importance	1	4.08	2	4.12	3	2.16	4	2.52	5	3.12				
Technology	BL			Usefulness	1	3.60	2	3.40	3	2.84	4	2.68	5	3.00				
H1.4	TM		F	Usefulness	1	3.72	2	3.68	3	2.20	4	3.16	5	3.40				
	BL			T-Improve-PU	1	3.60	2	3.40	3	2.84	4	2.68	5	3.00				
	TM			T-Improve-PU	1	3.72	3	3.68	3	2.20	4	3.16	5	3.40				
	BL			Ease-of-Use	1	3.12	2	2.96	3	3.24	4	3.24	5	3.20				
H1.5	TM		F	Ease-of-Use	1	2.96	3	3.00	2	2.24	4	3.32	5	3.44				
	BL			T-Improve-PE	1	2.60	2	2.69	3	2.84	4	3.08	5	2.96				
	TM			T-Improve-PE	1	3.92	2	3.96	2	2.44	4	3.00	5	3.32				
	BL			Satisfaction	4.18	Mean across WF – USE Model – 7 Determinants												
H1.6	TM		F	Satisfaction	2.78	Mean across WF – USE Model – 7 Determinants												
	BL			Ease-of-Learning	3.40	Mean across WF – USE Model – 4 Determinants												
H1.7	TM		F	Ease-of-Learning	2.10	Mean across WF – USE Model – 4 Determinants												
Att.& Behav.	BL			Attitude	1	3.32	2	2.40	3	3.36	4	3.20	5	4.00				
H1.9	TM		F	Attitude	1	2.16	2	1.80	3	2.60	4	2.40	5	1.85				
H1.10	BL			Behavior	1	3.6	2	3.92	3	3.84	4	4.12	5	2.84	6	3.0		
	TM		F	Behavior	1	2.6	2	2.0	3	1.92	4	2.56	5	2.24	6	2.6		
H1.8	BL			NPS					5.4	Detractors								
	TM	V		NPS							7.4	Passives						
Outcomes	BL			Awareness	1	4.28	2	4.60	3	3.76	4	2.60	5	3.25				
H1.11	TM		F	Awareness	1	4.16	2	4.28	3	2.76	4	2.92	5	3.25				
	BL			Info-Quality	1	3.76	2	3.92	3	3.44	4	2.72	5	3.40				
	TM			Info-Quality	1	3.40	2	3.40	3	2.76	4	2.80	5	3.04				
	BL			Goal-Alignment	1	3.60	2	3.84	3	3.04	4	2.56	5	3.08				
H1.12	TM		F	Goal-Alignment	1	3.76	2	3.76	3	2.84	4	3.00	5	3.20				

Table 48: CS-AF Summary Scorecard, Group 2 Analysis, Bondy 2020

The CS-AF Summary Scorecard between Group 1 and Group 2 follows.

CS-AF Element	WF	H1.1-H1.12 Valid/False		CS-AF Determinant	CS-AF Summary Statistics												
Context	MN			Async	2.6	PD	3.5	#P	1.3	CP	1.0	N	3.8	PP	3.5	T	1.6
H1.1	TM	V		Async	1.9	PD	4.7	#P	1.6	CP	1.3	N	5.0	PP	3.8	T	2.3
Process	MN	V		Cycle-Times	1	0.44	2	0.60	3	3.52	4	0.76	5	0.52			
H1.2	TM	V		Cycle-Times	1	2.28	2	1.72	3	3.22	4	3.86	5	1.72			
H1.2	MN	V		CT Acceptability	1	5.56	2	5.44	3	6.04	4	5.52	5	5.28			
H1.2	TM	V		CT Acceptability	1	5.80	2	5.84	3	6.00	4	5.72	5	5.60			
H1.2	MN	V		Lag-Times	1	0.36	2	0.48	3	1.04	4	0.40	5	0.48			
H1.2	TM	V		Lag-Times	1	0.88	2	1.72	3	1.12	4	1.60	5	1.28			
H1.2	MN	V		LT Acceptability	1	5.28	2	5.28	3	5.68	4	5.04	5	5.00			
H1.2	TM	V		LT Acceptability	1	5.88	2	5.76	3	5.84	4	5.52	5	5.44			
H1.3	MN		F	Info-Relevance	1	4.80	2	4.84	3	2.56	4	3.68	5	4.20			
H1.3	TM		F	Info-Relevance	1	3.52	2	3.96	3	2.40	4	2.88	5	3.04			
H1.3	MN		F	Info-Importance	1	4.72	2	4.72	3	2.44	4	3.68	5	4.16			
H1.3	TM		F	Info-Importance	1	4.08	2	4.12	3	2.16	4	2.52	5	3.12			
Technology	MN		F	Usefulness	1	4.44	2	4.60	3	2.36	4	3.92	5	3.76			
H1.4	TM		F	Usefulness	1	3.72	2	3.68	3	2.20	4	3.16	5	3.40			
H1.4	MN		F	T-Improve-PU	1	4.44	2	4.60	3	2.36	4	3.92	5	3.76			
H1.4	TM		F	T-Improve-PU	1	3.72	3	3.68	3	2.20	4	3.16	5	3.40			
H1.5	MN		F	Ease-of-Use	1	3.00	2	3.28	3	1.60	4	3.08	5	3.04			
H1.5	TM		F	Ease-of-Use	1	2.96	3	3.00	2	2.24	4	3.32	5	3.44			
H1.5	MN		F	T-Improve-PE	1	3.44	2	3.44	3	2.36	4	3.04	5	3.00			
H1.5	TM		F	T-Improve-PE	1	3.92	2	3.96	2	2.44	4	3.00	5	3.32			
H1.6	MN		F	Satisfaction	4.06	Mean across WF – USE Model – 7 Determinants											
H1.6	TM		F	Satisfaction	2.78	Mean across WF – USE Model – 7 Determinants											
H1.7	MN		F	Ease-of-Learning	1.26	Mean across WF – USE Model – 4 Determinants											
H1.7	TM		F	Ease-of-Learning	2.10	Mean across WF – USE Model – 4 Determinants											
Att.& Behav.	MN		F	Attitude	1	1.68	2	1.48	3	1.68	4	1.60	5	1.92			
H1.9	TM		F	Attitude	1	2.16	2	1.80	3	2.60	4	2.40	5	1.85			
H1.10	MN		F	Behavior	1	2.0	2	2.28	3	1.52	4	2.16	5	1.64	6	2.0	
H1.10	TM		F	Behavior	1	2.6	2	2.0	3	1.92	4	2.56	5	2.24	6	2.6	
H1.8	MN	V		NPS							7.8	Passives					
H1.8	TM	V		NPS							7.4	Passives					
Outcomes	MN		F	Awareness	1	4.04	2	3.96	3	3.00	4	3.20	5	3.68			
H1.11	TM		F	Awareness	1	4.16	2	4.28	3	2.76	4	2.92	5	3.25			
H1.11	MN		F	Info-Quality	1	3.68	2	3.76	3	2.60	4	3.20	5	3.44			
H1.11	TM		F	Info-Quality	1	3.40	2	3.40	3	2.76	4	2.80	5	3.04			
H1.12	MN		F	Goal-Alignment	1	3.44	2	3.56	3	2.68	4	3.32	5	3.52			
H1.12	TM		F	Goal-Alignment	1	3.76	2	3.76	3	2.84	4	3.00	5	3.20			

Table 49: CS-AF Summary Scorecard, Analysis between Group 1 and Group 2, Bondy 2020

Within Group 1 Summary Analysis, CS-AF Secondary Workflow Specific Determinants:

The context for the manual BP exam workflow, compared with the respective baseline, indicates an expected shift to a remote asynchronous workflow, which is indicative of a self-exam context. This manual workflow has transformed to become more distributed across more locations, with fewer participants, with fewer communities of practice, being somewhat more developing and short-term in nature, and with less turnover than the baseline workflow has. There were no surprises with these results. The group responded as predicted.

CS-AF reveals a marked improvement in the process times of the manual workflow, compared with the baseline, as participants recorded dramatic time reduction and overall workflow optimization. The fact that the manual workflow enabled participants for conduct the BP exam at home and on their own was the primary reason for the time optimization. However, the manual solution required recording of BP data by hand and having no contact with clinicians, which translated to minimal impact of the relevance and importance of the BP information obtained versus the baseline.

From a technology adoption perspective, participants did not view the manual BP exam process (device and procedure) to be particularly “useful” or “easy to use.” In fact, participants from Group 1 actually felt the process was less useful and easy to use than the traditional in-doctors-office BP exam did. Further exploration using the USE model did show participants to be more satisfied with the manual BP workflow, yet felt that the workflow as not as easy to learn, compared with the baseline.

Attitude and Behavior proved to be difficult metrics to advance with respect to the manual workflow; in every instance, all Attitude and Behavior responses decreased from an already low level recorded for the baseline workflow, other than for NPS (promoter) metrics. The results indicate a serious need for a much more comprehensive solution that motivates participants’ “attitude toward use” and “intent to use” the manual workflows which are required for successful adoption. The Net Promoter Score (NPS) advanced from a negative-state (Detractor) to a neutral-state (Passive), which was a significant advance, yet more opportunity exists for improvement here, as well.

Group 1 participants also felt that there was less awareness of their goals amongst clinicians in the manual workflow, compared with the baseline, and information quality was only enhanced by their own efforts to record manual BP readings. These factors contribute to the overarching opinion from Group 1 participants that there was a decrease in goal alignment with clinicians, indicating a belief that they were isolated with their BP data and had no collaborative exchange with clinicians during the process. Telehealth technologist will need to incorporate ways for patients to interact with them during self-care to positively impact the goal alignment of patients and the attainment of more beneficial outcomes.

Within Group 2 Summary Analysis, CS-AF Secondary Workflow Specific Determinants:

The context for the technology-mediated BP exam workflow, compared with the baseline, indicates a shift to a remote asynchronous workflow, as hypothesized, which is indicative of a self-exam context. This technology-mediated workflow has transformed from the baseline workflow to become more distributed across more locations, with fewer participants, with few communities of practice, being significantly more developing and short-term in nature, and with slightly less turnover than the baseline workflow has. There were no surprises with these results. The group responded as predicted to the contextual settings of the workflows.

CS-AF reveals a marked improvement in the process times of the technology-mediated workflow, compared with the baseline, as participants recorded dramatic time reduction and overall workflow optimization, as hypothesized. The fact that the technology-mediated workflow enabled participants to conduct the BP exam at home and on their own was the primary reason for the time optimization.

The technology-mediated solution automated the recording of BP data and enabled real-time visibility of all participants BP data with clinicians. Clinicians also had the prevision to send personal notes to participants, and all participants received a series of time-sequenced info graphs segmented to be relevant to the specific profile of each participant as proactive information push notifications. It is somewhat surprising to see that these technology features translated to only a slight positive movement on the relevance and importance of the BP information obtained for the technology-mediated workflow versus the baseline.

From a technology adoption perspective, participants did not view the technology-mediated BP exam workflow (Wise&Well and Omron device) to be significantly "useful" or "easy to use" compared with the baseline. Group 2 participants recorded a slight improvement in all areas of the workflow, except for Stage 3 (the BP exam), which was rated less useful and easy to use than the tradition in-doctors-office BP exam. Further exploration using the USE model did show participants to be more satisfied with the technology-mediated BP workflow, yet they felt that the workflow as not as easy to learn, compared with the baseline.

Similar to Group 1, the Attitude and Behavior also proved to be difficult metrics to advance with respect to the technology-mediated workflow; all Attitude and Behavior responses decreased from an already low level recorded for the baseline workflow for Group 2, other than the NPS metrics. The results indicate a serious need for a much more comprehensive solution that motivates participants' attitude toward use and intent to use the technology-mediated workflows for successful adoption. The Net Promoter Score (NPS) advanced from a negative-state (Detractor) to a neutral-state (Passive), which was a significant advance, yet more opportunity exists for improvement towards the promotability of the solution.

Group 2 participants also felt that there was less awareness of their goals amongst clinicians for the first 3 stages of the workflow in the technology-mediated workflow, compared with the baseline. There was, however, a slight increase awareness, information quality, and goal alignment for Stages 4 and 5, including a significant increase in goal alignment for Stage 4 of the tech-mediated workflow. The data reflects an improvement in the areas of treatment and post-exam, indicating that Group 2 participants felt more empowered and informed regarding their BP than they did in the baseline workflow. This is a small move in the positive direction, yet there remains a large gap in the front-end part of the workflow and the exam itself to more tightly integrate the collaborative efforts of patients with clinicians. Telehealth technologists will need to investigate ways to improve the collaborative workflow between patients and clinicians during remote self-care exams to positively impact the goal alignment of patients and more beneficial outcomes.

Between Group 1 and Group 2 Summary Analysis, CS-AF Secondary Workflow Specific Determinants:

Analysis between Group 1 manual workflow and Group 2 technology-mediated workflow participants indicates similar results. Both of the workflows proved to be successful with respect to process times; in fact, the Group 1 manual workflow was the most optimized in all stages of the workflow, except for Stage 3 the BP Exam. The data reflects the simplicity of the manual wrist-cuff workflow as being more optimized for all stages, except the BP Exam, since all BP data was recorded manually, in comparison the more automated readings of the technology-mediated workflow. Group 1 participants did not have any complex technology to content with, other than the simple wrist-cuff device itself. The tech-mediated workflow also scored better in the areas of information relevance and importance than for Group 1, indicating that the graph plots of real-time BP information, info graphs, alerts, and doctor messages slightly improved the quality of the information from the manual workflow.

Technology adoption determinants rated lower than hypothesized for both workflows; yet the technology-mediated solution proved slightly more useful than the manual solution for the first three stages of the workflow where the results flipped for stages 4 and 5. For the most part, participants from both groups indicated that technology could improve usefulness; however, the lowest rating for this variable was stage 3, indicating participants perspective that technology could be more impactful in the front- and back-ends of the respective workflows. Group 1 participants rated the manual workflow to be "easier to use" than Group 2 participants rated their respective workflow. The manual solution was reported to be an easier solution to use, compared with tech-mediated solution; however, Group 2 participants reported a higher rating for technology's ability to improve the ease of use, most significantly in the front-end process for Stages 1 and 2. Both participant groups agreed that the BP exam workflow would be more beneficial with automation on the formal registration and appointment scheduling aspects of the BP exam workflow. Group 1 participants were overall more satisfied with the manual workflow than Group 2 participants were with the tech-mediated workflow. Both groups found the "ease of learning" for the alternative workflow to be difficult, with a surprising, slight advantage in ease-of-learning reported by Group 2. The low scores reported for technology adoption by both groups will be explored further in this section.

Both groups rated variables for Attitude and Behavior for the alternative workflows evaluated as low overall for all stages. Group 2 scored slightly higher for all, but Stage 5 for “attitude toward using” and for “intent to use” Group 2 was also slightly higher than Group 1 for all stages but Stage 2. This data indicates a slightly improved attitude and behavioral intent of Group 2 participants to the technology-mediated workflow than to the manual workflow. However, it should be noted that of all the metrics incorporated in the CS-AF the attitude and behavior determinates were overall the lowest score reported. This underscores the tremendous importance of attitude and behavior on adoption in collaborative workflow and a target area for further discussion to follow.

The comparison of “outcomes” between groups indicated a similar reaction by participants for “awareness” and “information quality,” with lower scores from their respective baseline workflows in Stages 1, 2, and 3, and some minor improvements in Stages 4 and 5. These low scores indicate a lack of collaborative connection with clinicians in the alternative workflow. Participants stated that they would like more interaction and access to physician assistants (PAs) during the exam process to ask real-time questions and obtain support as needed. With respect to “goal alignment”, Groups 1 reported lower scores for the first 4 stages of the manual workflow and a slight increase in Stage 5. Group 2 reported a slight increase in goal alignment for Stages 1, 4, and 5, with stage 4 increase being significant compared with the baseline. Both groups reported that the problems areas in the workflow associated with goal alignment are primarily in the front-end process: pre-visit, register, and BP exam stages. This data confirms other CS-AF data and subjective comments from participants that clinicians seem detached with respect to their specific goals in the bassline workflow; this theme extends further in the alternate workflow, since being remote is a further disconnect from clinicians in an area that is already problematic. Further effort is need in the area of goal alignment and communication for patients to be satisfied with the remote nature of telehealth self-exams.

Hypothesis Results

All three primary hypothesis were proved to be valid (Alternative Hypothesis valid: Mean Baseline Workflow != Mean Technology-Mediated Workflow) for the HIT workflow study. Summary results of the hypertension BP exam workflow as it pertains to the primary hypothesis are listed below, followed by a detailed discussion of the results in Chapter 6.

Primary Hypothesis H1: *It is hypothesized that the CS-AF will produce* ***consistent data from a diverse set of parameters that will deliver a meaningful comparison*** *between the current-state and technology-mediated workflows evaluated.*

	Primary Hypothesis Description H1	**HIT WF** False/Valid
H_0 Null Hypothesis ɥ BLWF = ɥ TMWF	The CS-AF does not deliver a consistent data from diverse metrics to effectively evaluate collaborative technology mediated workflows.	
H_a Alternative Hypothesis ɥ BLWF != ɥ TMWF	The CS-AF does deliver a consistent data from diverse metrics to effectively evaluate collaborative technology mediated workflows.	Valid

Primary Hypothesis H2: *It is hypothesized that the CS-AF will produce an* ***effective approach*** *(model and methodology) that can be used to evaluate current-state workflow and a technology-mediated collaborative workflow for the Graphic Communications and Health Information Technology domains.*

	Primary Hypothesis Description H2	**HIT WF** Fales/Valid
H_0 Null Hypothesis ɥ BLWF = ɥ TMWF	The CS-AF does not deliver a cross-disciplinary set of metrics to effectively evaluate collaborative technology mediated workflows.	
H_a Alternative Hypothesis ɥ BLWF != ɥ TMWF	The CS-AF does deliver a cross-disciplinary set of metrics to effectively evaluate collaborative technology mediated workflows.	Valid

Primary Hypothesis H3 Generalizable Hypothesis: *It is hypothesized that versatility of the CS-AF will be viable as* ***a generalizable analysis approach*** *for both the GC workflow and the HIT* *workflow. It is further hypothesized that the CS-AF can be adapted to other domains where technology-mediated collaborative workflow is required.*

	Primary Hypothesis Description H3	HIT WF
		Valid
H_0 Null Hypothesis μBLWF = μTMWF	The CS-AF does not deliver a cross-disciplinary set of metrics that can be effectively transformed as a generalizable approach to evaluate collaborative technology mediated workflows.	
H_a Alternative Hypothesis μBLWF != μTMWF	The CS-AF does deliver a cross-disciplinary set of metrics that can be effectively transformed as a generalizable approach to evaluate collaborative technology mediated workflows.	Valid

5.8.2. Observations from the Hypertension Workflow Study

The hypertension study (the collaborative BP exam workflow) proved to be valuable exercise for evaluating the capability of the CS-AF and its expanded analysis methodology to investigate collaborative technology-mediated workflows. A variety of themes emerged from the study with respect to the learnings and limitations derived from the CS-AF approach and the data that was analyzed. Each of these themes is discussed below, followed by a final section on the implications for telehealth technology adoption.

Theme 1: Capture the context. The context of the workflow in its current state is an essential reference point to secure future evaluations and comparisons. Understanding the current snapshot in time for the target workflow is important. Barrett et al. posit that understanding the “context” for telehealth is an essential aspect of evidenced-based research and is critical to refinement of the application in this space [198].

Establishing a baseline view of the workflow from several specific vantage points, and then capturing an updated view of the same workflow from the same metrics for new technology-mediated improvements, enables a meaningful comparison and respects the research principles suggested by Ajzen et al. [66]. Ajzen et al. establish four different elements from which attitudinal and behavior entities may be evaluated: "the *action (work task)*, the *target* at which the action is directed, the *context* in which the action is performed, and the *time* at which it is performed" [emphasis theirs] [30]. These four evaluation elements (action [work tasks], target, context, and time) establish a consistent framework from which to observe, collect data, and evaluate the relationship between attitude and behavior. These four elements, suggested by Ajzen, have been incorporated into the CS-AF, with other metrics to achieve a comprehensive view of the changes in a workflow that is being transformed.

The CS-AF integrates "context determinants" from the Model of Coordinated Action (MoCA) because it ties together the context-centric construct from Ajzen with significant contextual dimension from CSCW and HCI literature into one integrated contextual model. The MoCA provides a way to tie up many loose threads related to context. More specifically, the researchers posit that the model provides "conceptual parity to dimensions of coordinated action that are particularly salient for mapping profoundly socially dispersed and frequently changing coordinated actions" [17:184]. Lee and Paine suggest that this model provides a "common reference" for defining contextual settings, "similar to GPS coordinates" [17:191].

As evidenced in this study, workflow under transformation will invariably change in time. Recording the contextual basis point of the target workflow is an important concept incorporated into the CS-AF that proved to be a valuable approach for this research. Incorporation of the seven MoCA determinants (Synchronicity, Physical Distribution, Participants, Communities of Practice, Nascence, Planned Permanence, Turnover) into the CS-AF generated a complete and easy to follow snapshot of each MoCA context determinant for each workflow and facilitated an approach to evaluate the change in context between each workflow.

Theme 2: A holistic task-focused view is needed. This study underscored the importance of an end-to-end view of the workflow and participants' perspectives at each stage in the workflow. Early examples of the TAM in field research incorporated data point intervals at various times pre- and post-technology-mediated implementation; however, in most instances, the TAM approach lacks the pre- and post-technology-mediated implementation view at the task level necessary to pinpoint where in the workflow the gain and gaps exist. Yousafzai et al. posit that the "lack of task-focus in evaluating technology" with the TAM has led to some mixed results. They further suggest that an opportunity to incorporate usage models for the TAM may strengthen predictability, yet caution is needed to manage model complexity [24], [25]. The CS-AF approach leads the evaluation effort down the path of a holistic view of the workflow taking into account all five aspects of the CS-AF for the entire workflow experience. The CS-AF integrates the Industrial Engineering practice of Value Stream Mapping (VSM) into the evaluation to collect and analyze quantitative time data for each step of the targeted workflow that are weakly defined in the TAM [24], [25]. The integrating of workflow stage-structure into the CS-AF added precision to the time and quality calculation associated with each major step in the workflow and the overall completion of the target work process task (BP exam workflow).

Incorporating VSM into the CS-AF established a common language and procedural methodology for characterizing the BP exam workflow in a quantitative manner; each step in the workflow was and measured for both the baseline and alternative workflow. The VSM process was successfully adapted for use in the CS-AF to establish a baseline view (time/task analysis) of the pre-implementation or current-state BP exam workflow, and then repeated with the technology-mediated and manual workflows (future-state) for successful analysis and evaluation of the gain and gaps. By identifying each significant step in the workflow, and collecting the time and quality data, a value stream map was created, indicating the total time for the workflow and identifying all quality issues throughout the BP exam process. This approach confirms the important role of "task and technology" stated by technology adoption experts Brown, Dennis, and Venkatesh [199] in research on technology adoption. Incorporating VSM with the CS-AF proved to be a valuable guiding focus for this study and was instrumental in uncovering specific gains and gaps for the workflow evaluated with formal measurement and analysis at the task level that is often invisible to developers.

Theme 3: Time equals money, but is not the only answer. Further value of collecting and analyzing task data using the CS-AF approach is evidenced in the potential use of process times for financial analysis of technology adoption. Although financial analysis is outside the scope of this research, collection of the task-time data enables further cost-effectiveness analysis (CEA) analysis if necessary. Woertman et al. posit that CEA is an integral part of technology adoption assessments globally in health care [200]. Their research underscores the importance of calculating the cost associated with a current process and evaluating the financial benefit of the new innovation. Understanding the process times of the existing workflow and comparing the process times of the proposed workflow solution is a best practice in health care. Most of the management metrics associated with CEA are derived from process times and are calculated as efficiency gains or gaps.

This research identified specific time comparisons between the baseline workflow and then alternative workflows at the task level. Participants across the board were pleased with the optimization of the alternative workflows; however, even with a marked improvement in time, participants did not feel the solutions were more “useful,” and their attitude and behavioral “intent to use” was actually reduced, compared with the baseline workflows. The data underscore the importance of process time data and also identifies that, although time-optimization is crucial, it is far from being the only key to successful collaborative workflow adoption. It is, therefore, essential that technology solutions providers realize that time optimization is just the beginning of creating a successful collaborative technology-mediated workflow.

Theme 4: Technology is not a substitute for 1:1 communications. The CS-AF captured an important assessment of information quality across the stages in the workflows evaluated. The data showed a large gap in the expectations of participants with respect to communication with clinicians during the telehealth experience. Technology alone is not the solution to better information quality. Group 2 participants were exposed to a variety of “automated” communications options in the technology-mediated workflow, including graph-plots of real-time BP information, info graphs, alerts, and doctor messages; yet these technology enhancement only showed a slight improvement in the quality of the information from the baseline and manual workflow. The collaborative information flow between patient and the clinical team is under-supported for telehealth. Practitioners are not trained, nor are equipped to support a growing network of remote asynchronous patients, and the technology is not designed for real-time in-app support and communications. As growth in telehealth continues, expanded capability and resources are needed in the area of patient-site facilitators for telehealth. In a study of the role of patient-site facilitators in tele-audiology, researchers Coco et al. summarized their findings, identifying gaps with both the number of facilitators in support of the growing telehealth demand and the associated training to equip these individual with the knowledge needed to successfully support remote telehealth patients [201].

Telehealth patients also bear some responsibility for the connection and flow of quality information in the telehealth workflow. Juin-Ming Tsai et al., in their research of "acceptance and resistance of telehealth" research, suggest that "… individuals should establish the concept of healthy self-management and disease prevention. Only when the public is more aware of self-health management can they fully benefit from telehealth services" [202:9]. The migration to self-health requires added commitment of patients towards the information and processes associated with telehealth. Until patients' attitude and behaviors are accepting of this added responsibility, telehealth adoption will be challenged, regardless of the technology available and the support of patient-site facilitators. The distinct requirement for quality information exchange across telehealth workflows will put further demands on both providers and patients for timely communications, monitoring, and support.

Theme 5: Technology that is easy to use, is not always adopted. The integration of TAM determinates for "usefulness" and "ease of use" within the CS-AF uncovered interesting results associated with collaborative workflow adoption in telehealth. This research reveals the complexity of technology-mediated innovation and the synchronization of the features with users' propensity to adopt. Adoption researchers have shown that Perceived Usefulness has a significant impact on technology adoption and Ease of Use is less of a determinate for adoption (Juin-Ming, et al., 2019, Chen & Hsiao, 2012; Cheng, 2012; Cresswell & Sheikh, 2012; Despont-Gros et al., 2005; Kim & Chang, 2006; King & He, 2006; McGinn et al., 2011; Melas et al., 2011; Morton & Wiedenbeck, 2009; Yusof et al., 2008). Juin-Ming et al.'s research states, "Telehealth has a close connection with individual health. Therefore, a user-friendly interface is not the first priority. In other words, as long as telehealth can improve users' quality of life and provide better healthcare service, users will be more likely to try the functions that it provides" [202:7]. The researchers go on to further state that developers should focus on “perceived usefulness” to help patients find the practical integration path to incorporating the technology-mediated solution into their individual health management plan. “Therefore, individuals should establish the concept of healthy self-management and disease prevention” [202:9].

Developing an easy-to-understand user experience is an important aspect of the solution; however, the research shows the solution will need to be determined as a useful and viable solution that has practical use on a daily basis for patients to increase their intention to use. Obviously, there is also a direct connect between users’ attitudes and behavior and their perception that the technology-mediated workflow will be a useful experience. The important point verified in this study is that user perception on Ease of Use and Perceived Usefulness both scored lower than were hypothesized; the reason was not necessarily the user interface, but was most likely the misalignment on the complete solution with the integrated way that users would like to experience telehealth. Both the provider facilitation and personal health management come into play as enablers to adoption.

Theme 6: Relative advantage drives attitude and behavior to adopt. Ajzen et al.’s research found a high correlation between attitude and behavior, specifically when there was both a direct correspondence between attitude and behavior [66]. The researchers suggest that “to predict behavior from attitude, the investigator has to ensure high correspondence between at least the target and action elements of the measures he employs” [66:188]. The CS-AF evaluates both behavior and attitude across the five stages of the BP exam workflow. The data reveal a more negative “attitude towards”, and “behavioral intent to use” the alternative workflows from the baseline workflows measured. Participants were not convinced that the alternate solution provided enough of a relative advantage to deem the alternative workflow as “useful” enough to shift their beliefs.

This is an important understanding uncovered by other researchers in telehealth technology adoption. Zanaboni and Wootton's research build off of Rogers' Diffusion of Innovations research to investigate how adoption occurs in telehealth. The research finds that, of the five Rogers attributes for adoption (relative advantage, compatibility, trialability, observability, and complexity), relative advantage is the key determinant effecting attitude and behavior to adopt in telehealth [203:2]. The importance of helping users identify with the "advantages" of the technology-mediated workflow is the crucial determinant of the speed of adoption of technology in healthcare, as reported by Greenhalgh et al. [204], and also by Scott, et al. [205].

Theme 7: Goal alignment requires group alignment. As large populations shift to telehealth, some of the key attributes of goal alignment, such as "awareness" and "common ground", that may be instinctive in the face-to-face setting may be overlooked in remote asynchronous telehealth workflows. Reddy et al. posit that "awareness" is not as natural, and breaks-downs occur in technology-mediated telehealth workflows [206:269]. Furthermore, technology-mediated telehealth solutions can disrupt the traditional approach that healthcare providers have toward establishing common ground, or shared goals, amongst their patients [207].

The CS-AF incorporates determinants for evaluating both awareness and goal alignment across the stages in the BP exam workflow. The results of the analysis showed a slight positive movement in goal alignment and awareness with the technology-mediated solutions, yet the progress in this area was still not acceptable. Much more emphasis is needed in connecting the clinician team with remote patients to deliver holistic solutions for telehealth that allow patients to feel as connected toward their goals in a remote context as they feel in the face-to-face setting. Eikey et al. state that "HIT needs to be designed to support specific processes of collaborative care delivery and integrate the collaborative workflows of different healthcare professionals [44:270]. Researchers Whitten and Mackert suggest that providers have an integral role in the deployment of telehealth solutions, including the use of project managers and remote-care facilitators to show overall provider awareness and to establish dependable common ground with remote patients for telehealth to be adopted widescale [208:517-521].

5.8.3. Implications for Telehealth

This research has some direct and immediate implications for technology-mediated initiatives in telehealth that impact practitioners, patients, and developer-solution providers. The implications for each of these communities are significant to the overall acceptance and mainstream adoption of telehealth solutions and in healthcare.

Practitioner: The telehealth community is clearly a unique ecosystem, unlike the traditional healthcare system in most every way. For the provider-clinician community to be successful with telehealth, it must be viewed as an entire new implementation paradigm that is complementary with on-site care system, yet with an entirely different set of objectives, leadership, and sponsorship. Practitioners that approach telehealth with the same mind set as the in traditional on-site context will certainty have difficulty with telehealth technology implementations and adoption.

Practitioners need to understand that technologies are moving at a faster rate than the medical system's ability to incorporate new capability into their operations. Barrett et al. state, "Advances in technological developments significantly outpace the ability of care systems to reform themselves in a way that can provide the enabling platform necessary for wider deployment of telecare" [198]. The pace of technology will not slow. It is more likely to accelerate; therefore, practitioners must establish permanent operational processes for continuous technology adoption. This approach will ensure that a pipeline of new technologies at various stages of maturity are properly vetted, prototyped, and integrated into the telehealth system.

Practitioners incorporating telehealth services must learn to redefine the context of a "patient" and the support mechanisms that will empower patients to be successful in their remote and asynchronous environments. Clinicians will need to establish new teams, including remote-care facilitators, project managers, and technical support specialists that are properly trained and assigned to the charter of telehealth delivery [208].

Included in the requirement for remote patient-centric thinking, providers will need to be proactive with respect to security and privacy. Proper protocols and technology infrastructure are needed to allow the telehealth solutions to be led by a structured deployment system that anticipates all possible threats. This includes inclusion of provider resources equipped to onramp new patients, educate them on the systems, and address all concerns that they may have. Sanders et al.'s research on barriers to participation adoption found that some telehealth patients expressed concern with being "dependent" on technology [209]. Greenhalgh et al. reported findings that telecare users had concerns about security and that there was a "perception of surveillance" [204]. Practitioners will need to understand that many of telehealth users are elderly and may have sight, hearing, and dexterity issues, amongst the typical anxiety concerns evidenced in this demographic's perception of new technology [202], [210].

Developer-solution provider: Developers of telehealth technology can benefit from this research by shifting attention to the functional use of the technology in the field with real patients through iterative agile development involving lead-users. Since the telehealth ecosystem is just now formulating, real insight into the unmet needs of patient will be found by working directly with patients that have an interest in adopting telehealth; they can be spokespeople for their community needs [211], [212].

Developers need to comprehend the findings in this study associated with the subtle migration of non-adopters to adopters and realize that the primary motivator is a relative advantage that triggers attitude towards use and behavioral intent to use, which feeds perceived usefulness of the technology-mediated solution for new telehealth users [203], [204], [205]. Savvy developers will comprehend this adoption sequence and learn to develop more holistic solutions that incorporate the needed services components that make the interpretation of relative advantage and immediate usefulness the core of the initial experience and onboarding process of new telehealth users.

Developers will also need to explore the technology's future space and contemplate new systems design platforms that integrate a variety of telehealth solutions into a common patient dashboard, so that patients can quickly habituate with a user experience paradigm. This approach will allow patients to gain additional relative advantage by adding in additional telehealth capability into an already familiar framework that they are comfortable with [213].

Developers will need to explore new ways to collaborate with the practitioner community during each stage in the product development lifecycle. This approach will facilitate better integration with providers and more targeted solutions that address the real concerns of users and practitioners. Researchers Yen and Bakken advocate an extended development lifecycle with emphasis on the front-end part of the process and iterative in nature with lead-users. [214], [7]. The telehealth development community is not as established as other sectors, such as consumer electronics and business software solutions. Developers in telehealth need to investigate best practices in more mature sectors and incorporate those development lifecycle practices into their standard operating procedures to ensure predictability.

Patients: Patients have a big responsibility in the telehealth ecosystem, beginning with two key responsibilities: (1) a mind-set for self-care health management, and (2) a technology-adoption mind-set. Telehealth users have a responsibility to establish their own health plan in a manner the improves their own attitude to use and adopt telehealth solutions and to advocate for their specific healthcare plan with the practitioner community. "Because most chronic conditions are related to lifestyle, self-management represents an opportunity for direct intervention at the individual level with the potential for favorable impacts on health and health behaviors" [202:9]. Telehealth users should spend the time to define a formal healthcare plan in a manner the fleshes out the ambiguity for themselves and provides a formal reference for providers to better understand their specific healthcare needs.

Equally as important as the self-management mind-set is the need for future telehealth users to have a technology-adoption mind-set. Patients need to know that there is a learning curve associated with technology and assume that there will be some start-up difficultly, but work to overcome these barriers with a mind-set that the upside use of the technology far out-weighs the hurdles to establishing a new norm. Bem's research in self-perception theory states that when individuals rely on their past behavior as a guiding force towards new adoption, they wrongfully position themselves to poorly perceive the relative advantage of the new technology [215]. Davis, the originator of the TAM, states that individuals accept a technology to the extent that they believe it will meet their needs; when users shift their mind-set to include the cost of adoption, they are more accepting of a delay in relative advantage to accommodate the learning curve [22]. It is incumbent on telehealth users to commit to the switching costs associated with learning and habituating on a new way of doing things, such that the long-term benefits of telehealth can be realized.

Chapter 6

Evaluation of Research Objectives, Contributions, Limitations

6.1. Evaluation of Research Objectives

Objectives for this research focused on two primary goals: (1) develop a cross-disciplinary methodology to evaluate and analysis the gains and gaps associated with technology-mediated collaborative workflow adoption and (2) conduct two empirical studies to exercise the effectiveness of the analysis framework and to refine the functional application of the framework for use as generalizable approach that can be transformed for use in multiple domains. The initial concept of the Collaborative Space-Analysis Framework (CS-AF) was used in the first empirical study involving a graphic communications workflow. Learnings from the first study were incorporated into a revised CS-AF. The refined CS-AF included added features with the addition of the Lund and NPS models and a more extensive statistical analysis methodology. Included in the enhanced statistical analysis is a CS-AF Summary Scorecard which was used to summarize the second empirical study: a hypertension exam workflow that compared a typical BP exam with a telehealth technology solution aimed at better doctor-patient collaboration.

Two empirical studies conducted for this research facilitated an immersive opportunity to engage with real users in a live workflow scenario and to implement, test, and evaluate the CS-AF methodology to evaluation specific enhancement to the targeted workflows. The use of CS-

AF for two diverse collaborative technology-mediated workflows allowed for practical application of the approach and opportunity to refine the methodology through each subsequent study. Both the GC Workflow study and the HIT workflow study proved to be beneficial in answering the research questions and the associated hypothesis.

The following evaluation and analysis of the research questions and associated hypothesis originally presented in this research is conducted in reference to the results from the two empirical studies using the CS-AF. Three research questions were presented in this research; each research question was associated with a number of hypotheses that were tested and evaluated throughout this research. A summary evaluation of each research questions and the primary hypotheses associated with the specific research questions follows.

Research Questions and Primary Hypotheses:

RQ1: *What set of* ***cross-disciplinary metrics and consistent methodology*** *are necessary to effectively evaluate a technology-mediated collaborative workflow?*

Primary Hypothesis H1: *It is hypothesized that the CS-AF will produce* ***consistent data from a diverse set of parameters that will deliver a meaningful comparison*** *between the current-state and technology-mediated workflows evaluated.*

One of the primary objectives for this research was to develop a cross-disciplinary framework to evaluate collaborative workflows. The first hypothesis suggests that the unique combination of evaluation metrics compiled into the CS-AF, from a variety of domains, will yield a diverse view of the workflows, such that valuable comparative results (gains and gaps) can be evaluated. The CS-AF introduces a unique collection of evaluation metrics that have been integrated for a collective view. Some of the models and metrics have been adapted for the specific use of evaluating collaborative workflows. The modification and expansion of reference models is a common practice in research, and it is a key concept that is foundational to the formation of the CS-AF approach. Various evaluation models used to comprehend collaborative workflow, such as the TAM used in this research, have a history of being modified and extended to pinpoint the focus of a particular research initiative. The original TAM was actually an integrated model of Davis' technology adoption determinants such as PU and PEU [22], with the Behavioral Science determinants from Ajzen's TRA [66], [67]; attitude towards use, and behavioral intent to use [84].

In a two-part meta-analysis of empirical studies using the TAM for a wide variety of technology workflow scenarios from email to telemedicine technology, Yousafzai et al. state that the TAM is ideal model for a variety of applications, and it can be successfully modified to address weakness in the original form. The authors seem to believe that the "lack of task-focus in evaluating technology" has led to some mixed results. They further suggest that an opportunity to incorporate usage models for the TAM may strengthen predictability, yet caution is needed to manage model complexity [24], [25]. Incorporating Value Stream Mapping (VSM) into the CS-AF provides a complementary aspect to the analysis that allows for quantification of time series data at the workflow task level. The integration of VSM with the TAM features enhances the characterization of the workflow with comparative cycle- and lag-times at the task level. Critics of the TAM also believe that putting too much weight on external variables and behavior intentions, and not giving enough consideration towards user goals in the acceptance and adoption of technology, are limitations of the TAM in all its forms [89].

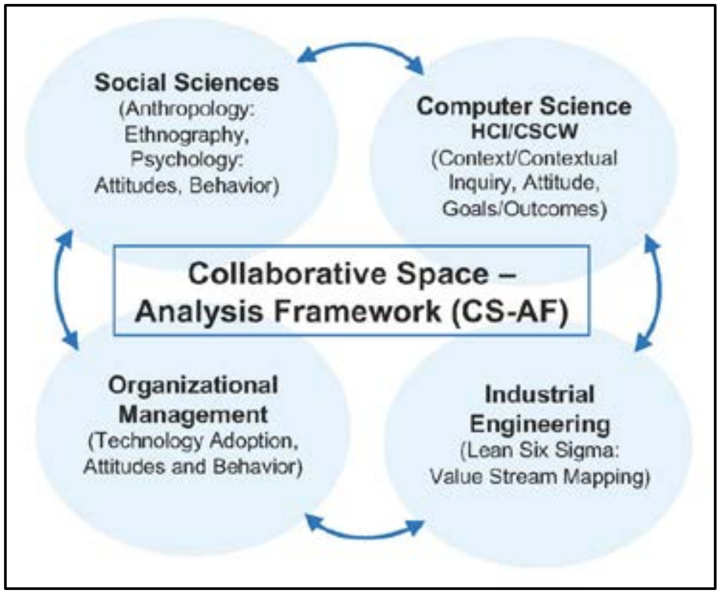


Figure 62: Cross-Disciplinary elements of the CS-AF, Bondy 2020

The CS-AF incorporates provisions to acknowledge user goals and outcomes in an effort to improve on limitations of the TAM. In their research of CSCW Models and Frameworks, researchers Neale, Carroll, and Rosson introduce the "Activity Awareness Model" (referenced in the Related Works section) and identified three historic issues associated with evaluating collaborative workflows: logistics of remote locations, complex number of variables, and the need to validate the re-engineered of future-state workflow [13]. The researchers conclude by stating, "Few methods have been developed with creating engineering solutions in mind. It is possible, but researchers must be continually cognizant about how data collection and analysis methods will translate into design solutions" [13:114]. At the core of the research findings by Neal et al. is the notion that the re-engineered workflow needs to be examined in its natural setting in order to understand the collaborative impact of the technology-mediated enhancements and that this is the "central priority in CSCW evaluation." The researchers summarize that "better evaluation approaches are critical to the successful development of CSCW applications" [13:120]. Attributes from the Activity Awareness

Model, such as goal alignment and goal awareness, were incorporated into the CS-AF to address some of the shortcomings with the TAM.

Other CS-AF components, such as the MoCA [17] and CSM [44], are theoretical models, offered to the research community as a "suggested approach" to be refined and tuned for subsequent field studies. The MoCA was integrated into the CS-AF because it ties together the significant contextual dimension that have been covered in CSCW and HCI literature into one integrated contextual model. The MoCA provides a way to tie up many loose threads. More specifically, the researchers posit that the model provides "conceptual parity to dimensions of coordinated action that are particularly salient for mapping profoundly socially dispersed and frequently changing coordinated actions" [17:184]. Lee and Paine suggest that this model provides a "common reference" for defining contextual settings, "similar to GPS coordinates" [17:191].

The Collaboration Space Model (CSM) is a theoretical framework that consists of four key components: (1) Context, (2) Technology, (3) Process, and (4) Outcomes. CSM is a useful reference model for categorizing the various aspects of collaboration, based on a systematic HIT literature review of 943 articles over 25 years. The CSM suggests the critical attributes for exploration of collaborative workflows in healthcare, yet the CSM was not field-tested. Eikey et al. suggest that future research using the CSM should "focus on the expanded context of collaboration to include patients and clinicians, and collaborative features required for HIT systems" [44:274]. This research was designed to execute on observations made by Eikey et. al. and others in the HIT, Organization Management, CSW/HCI, and Behavior Sciences domains, using a field engagement methodology that integrates these diverse metrics into a replicable process and structured summary evaluation report.

	Primary Hypothesis Description H1	**GC WF**	**HIT WF**
		False/Valid	False/Valid
H_0 Null Hypothesis μBLWF = μTMWF	The CS-AF does not deliver a consistent data from diverse metrics to effectively evaluate collaborative technology mediated workflows.		
H_a Alternative Hypothesis μBLWF != μTMWF	The CS-AF does deliver a consistent data from diverse metrics to effectively evaluate collaborative technology mediated workflows.	Valid	Valid

This research validates that the diverse set of cross-disciplinary metrics (e.g., MoCA, VSM, TAM, USE, and NPS), can be effectively integrated to form a viable framework and analysis methodology for the evaluation of collaborative workflows. The CS-AF survey instrument, analysis methodology, and summary scorecard enable a replicable approach for observing, reporting, and evaluating a technology-mediated collaborative workflow, compared to a baseline workflow. The information collected from the baseline and alternative workflows using the CS-AF was consistent, and the analysis and reporting methodology was predictable and delivered consistent results. The CS-AF summary data and summary scorecard provided a unique and comprehensive evaluation of the two workflows, compared with meaningful insights into the gain and gaps introduced by technology across my key functional areas (Context, Process, Technology, Attitude and Behaviors, and Outcomes).

Secondary Hypotheses H1.1-H1.12 – CS-AF Workflow Specific Determinants:

The secondary hypotheses targeted at the workflow specific determinants of the CS-AF are summarized in the following table; the validation for each specific secondary hypotheses are determined by the data collected from the CS-AF survey data. The specifics regarding the secondary hypotheses and results for the GC and HIT empirical studies are evaluated and discussed in detail in Chapter 5 and 6, respectively.

Secondary Workflow Specific Hypothesis H1.1 - H1.12	GC-WF	HIT-WF
Context		
H1.1: Context Hypothesis: It is hypothesized that technology-mediated workflows are more asynchronous and remote, compared with current-state workflows.	**H_0 Null Hypothesis Valid**	**Ha Alternative Hypothesis Valid**
Process		
H1.2: Process Time Hypothesis: It is hypothesized that technology-mediated workflows are more streamlined (i.e., require less time), when compared with current-state workflows.	**Ha Alternative Hypothesis Valid**	**Ha Alternative Hypothesis Valid**
H1.3: Information Quality Hypothesis: It is hypothesized that technology-mediated workflows deliver better information quality, when compared with current-state workflows.	**H_0 Null Hypothesis Valid**	**H_0 Null Hypothesis Valid**
Technology		
H1.4: Perceived **Usefulness Hypothesis:** It is hypothesized that technology-mediated workflows are perceived to be more useful, when compared with current-state workflows.	**Ha Alt. Hypothesis Valid**	**H_0 Null Hypothesis Valid**
H1.5: Perceived **Ease-of-Use Hypothesis:** It is hypothesized that technology-mediated workflows are perceived to be easier to use, when compared with current-state workflows.	**Ha Alt. Hypothesis Valid**	**H_0 Null Hypothesis Valid**
H1.6: Satisfaction Hypothesis: It is hypothesized that technology-mediated workflows are perceived to be more satisfying, when compared with current-state workflows.	**NA – not included for GC CS-AF**	**H_0 Null Hypothesis Valid**
H1.7: Easy-of-Learning Hypothesis: It is hypothesized that technology-mediated workflows are easier-to-learn, when compared with current-state workflows.	**NA – not included for GC CS-AF**	**H_0 Null Hypothesis Valid**
Attitude and Behavior		
H1.8: Promotability Hypothesis: It is hypothesized that technology-mediated workflows are more highly promoted, when compared with current-state workflows.	**NA – not included for GC CS-AF**	**Ha Alternative Hypothesis Valid**
H1.9: Attitude-Toward-Use Hypothesis: It is hypothesized that the attitude to use technology-mediated workflows is more positive, when compared with current-state workflows.	**Ha Alt. Hypothesis Valid**	**H_0 Null Hypothesis Valid**
H1.10: Behavioral Intention Hypothesis: It is hypothesized that the behavioral intention to use technology-mediated workflows is more positive, when compared with current-state workflows.	**Ha Alt. Hypothesis Valid**	**H_0 Null Hypothesis Valid**
Outcomes		
H1.11: Awareness Hypothesis: It is hypothesized that technology-mediated workflows increase the awareness of information sharing needs, when compared with current-state workflows.	**Ha Alt. Hypothesis Valid**	**H_0 Null Hypothesis Valid**
H1.12: Goal Alignment Hypothesis: It is hypothesized that technology-mediated workflows increase goal alignment, when compared with current-state workflows.	**Ha Alt. Hypothesis Valid**	**H_0 Null Hypothesis Valid**

Table 50: Secondary Hypotheses and CS-AF Metrics, Bondy 2020

The CS-AF, in its initial form, established a well-integrated cross-disciplinary set of comparison metrics that allowed a complete and consistent view of both the current-state and the technology-mediated workflows, such that the gains and gaps between the two workflows could effectively be evaluated. The CS-AF used in the GC workflow study proved the H1 hypothesis valid; however, the study revealed opportunities for improvement in the statistical analysis methodology. A more structured analysis methodology was developed for the CS-AF and applied to the HIT workflow study. Additional evaluation metrics for ease of learning, satisfactions, and promotability were added to the CS-AF to enable a more comprehensive view of the workflows to be evaluated. The CS-AF also expanded the analysis methodology of subjective responses to extract prevailing themes from the responses.

RQ2: *Do the metrics and methodology introduced in the CS-AF produce an* ***effective evaluation*** *of the technology-mediated collaborative workflow for the graphic arts and hypertension workflows evaluated?*

Primary Hypothesis H2: *It is hypothesized that the CS-AF will produce an* ***effective approach*** *(model and methodology) that can be used to evaluate current-state workflow and a technology-mediated collaborative workflow for the Graphic Communications and Health Information Technology domains.*

CS-AF Summary Analysis: GC – HIT Workflow Comparison

The initial empirical study targeted at the Graphic Communications (GC) workflow using the CS-AF was a useful, initial trial to exercise in order to validate the CS-AF approach. With my more than three decades of experience in the GC domain, conducting an initial empirical study in this area was helpful, since the primary variables of study were the CS-AF itself and not any unfamiliarity with the domain. This approached allowed a deeper concentration on the CS-AF survey instrument, field engagement methodology, and summary diagnostics. The GC workflow study proved the CS-AF to be a viable approach for evaluating workflows, and it also helped to identify certain limitations. Specific learnings from the GC empirical study were related to the statistical evaluation methodology when comparing the pre-post CS-AF survey data. For the initial GC study, data was analyzed for the mean results of each question at the survey-question, or determinant-level. This approach enabled a high-level view of the survey distributions for comparison between the workflows, but they lacked the rigor to identify statistical significance across each stage in the workflow. It was clear from the initial GC study that a more extensive statistical approach was necessary in order to compare the mean values between the two workflows and to suggest a replicable methodology that can be transformed to other domains. The subsequent HIT workflow study expanded on the CS-AF statistical approach to deliver a more rigorous and replicable statistical approach that adds precision and confidence to the workflow evaluation.

In addition to developing a more thorough statistical approach, the GC study also helped to identify opportunities for a more expanded view of technology adoption and behavior. It was determined that incorporating the Lund USE Model [26] into the CS-AF would add two valuable determinants (Ease of Learning and Satisfaction) to the TAM [22] technology adoption metrics (Ease of Use and Perceived Usefulness), allowing for a visual comparison of the statistical results for all four metrics in a radar chart. It was also determined that the Attitude and Behavior section could be expanded to include the Net Promoter Score (NPS) Model [27], which enhances the CF-AF to include metrics regarding the users' attitude towards promotability of the workflow to others.

As a result of the GC empirical study, the CS-AF statistically analysis and reporting methodology was refined, and the CS-AF was expanded to include the USE and NPS models.

These refinement and additions to the CS-AF made for a more robust and predicable approach, as evidenced in the second HIT empirical study. Detailed results of the GC workflow study can be found in Chapter 5.

CS-AF Summary Analysis: HIT Collaborative Workflow

The second empirical study using the CS-AF was conducted in a completely different domain in efforts to test the transformability of the CS-AF to different domain. The field engagement plans for this study were made prior to the COVID-19 pandemic, and needed to be refined prior to the live engagement to accommodate the added constraints imposed by the pandemic. The added restrictions of the pandemic caused a minor setback in terms of the field engagement process and protocol, yet they positively increased the timely nature of investigating adoption of telehealth workflow. The pandemic validated the tremendous need for characterization of HIT workflows and better precision in the evaluation of technology-mediated enhancements in this domain.

The targeted workflow evaluation of a traditional (in-doctor's-office) hypertension exam, compared with a technology-mediated (remote-asynchronous telehealth) hypertension exam was performed. The dynamics of these workflows proved to be appropriate for the conditions of the pandemic, with minor modification to the baseline exam protocol, the distribution of devices, participants instructions, and survey deployment. Each of these obstacles were addressed to establish confidence and predictability with all test participants. The real nature of the pandemic also personified the extreme importance of the remote-asynchronous context of the technology-mediated alternative workflow evaluated and the importance of real-time BP data for participants.

The on-boarding and training of test participants was conducted virtually through video conferencing and expanded documentation that was delivered in printed form and digitally. In addition, a support website was constructed for participants to access. Previsions were made with the clinical team involved in this study for secure hand off of all study materials in sterile, individually packaged bags, distributed by the clinical team. Surveys were conducted virtually in semi-structed video forums, where questions were explained and participants were open to ask clarifying questions, in a similar manner as they might do in person.

As a result of learnings from the GC workflow study, and subsequent refinements to the CS-AF, the HIT workflow study was conducted with expanded metrics (USE and NPS) and a more precise statistical analysis methodology. The CS-AF statistical analysis and reporting methodology was refined, prior to the HIT workflow study, to include a more robust and predicable approach for analyzing and reporting survey data from the pre-post workflows studied. The research design for the HIT workflow included a participant sample size that would be meet a statistically acceptable number of participants, versus the small number of participant-users that were involved in the GC workflow study. Based on hypertension age-band/gender criteria used by the researchers in this domain [178], [179], [186], it was determined that participants from six age bands would be selected. It was further determined that recruiting participants in matched pairs would allow a smaller sample size, while increasing the complexity of recruiting the exact match for the age band and gender criteria. To meet the minimally acceptable number of participants, calculation for effect size, Type 1 error, least powers, and standard deviation, estimated a sample size of 25 matched pairs was required. A minimum of four male and four female hypertension patients from each of the six age bands were selected for this study. From more than 80 candidate responses, 25 matched pairs (age-band/gender), equaling 50 patient participants, were included in the hypertension workflow study. Within each pair, subjects were randomly assigned to two groups; Test Group 1: manual BP workflow, and Test Group 2: technology-mediated BP workflow.

The study included the prescribed pre-post CS-AF workflow evaluation surveys for both groups; one survey was conducted at the start of the study in reference to the baseline BP exam workflow, followed by a minimum three-week alternative workflow trial and the final survey. Based on the survey data collected, two levels of statistical analysis were performed: Repeat-Measure Analysis of Variance (rANOVA), and matched-pairs *t*-tests.

The rANOVA was incorporated to compare mean values for each CS-AF determinant within and between groups. When statistically significant change in mean values occurred (p-value<.05), further pair-wise *t*-test analysis was conducted to compare means at the workflow stage-level; positive and negative changes in mean values were recorded as a method for evaluating the gains and gaps between the workflows tested. This statistical approach proved to be a valid and replicable method for evaluating the workflows studied. The added rigor and precision of this approach has increased the confidence of the study results, as well as increased the replicability of the methodology for more generalized use in other domains. A complete description of the statistical methods and empirical study results for the hypertension workflow are available in Chapter 5.

In addition to the expanded statistical approach used for the CS-AF, more precision was also attempted for the collection and reporting of the subjective data from the surveys. The CS-AF incorporates 15 subjective questions across the 5 sections of the survey which are designed to encourage participants to express further details regarding the specific aspect of the CS-AF in question. Results from the subjective questions were collected and analyzed to determine significant themes that might complement or contradict the statistical findings from the Likert-scale survey mean-data that was analyzed via rANOVA and paired *t*-test. There was a potential for 1500 subjective responses across the entire CS-AF survey instrument (15 questions x 50 participants x 2 surveys). Surprisingly, a large number of participants took the time to add additional subjective comments: this added data provided an enormous amount of content to review and process into various thematic categories. Initially, subjective questions we tallied and parsed based on the positive vs. negative response. Then, the subjective responses were analyzed for specific themes; the prevailing themes and supportive quotations from participants were summarized for each section of the CS-AF and tied to the statistical finding from the survey.

Advancement of the CS-AF approach for the HIT workflow empirical study was significant. The larger sample size, expanded CS-AF metrics, statistical methodology and summary scorecard, and subject response analysis were all enhanced for this second field study. The formalization and predictably of the approach position the work for further use in the HIT domain and other domains that exhibit complex collaborative workflows that might be enhanced by technology. The determinant-level sub-hypothesis for this research was addressed individually for each specific empirical study (GC workflow: Chapter 4, HIT workflow Chapter 5).

	Primary Hypothesis Description H2	**GC WF**	**HIT WF**
		False/Valid	Fales/Valid
H_0 Null Hypothesis ɥ BLWF = ɥ TMWF	The CS-AF does not deliver a cross-disciplinary set of metrics to effectively evaluate collaborative technology mediated workflows.		
H_a Alternative Hypothesis ɥ BLWF != ɥ TMWF	The CS-AF does deliver a cross-disciplinary set of metrics to effectively evaluate collaborative technology mediated workflows.	Valid	Valid

RQ3: *Does the CS-AF and methodology deliver an* ***effective generalizable approach*** *to evaluate technology-mediated collaborative workflows across different domains?*

Primary Hypothesis H3 Generalizable Hypothesis: *It is hypothesized that versatility of the CS-AF will be viable as* ***a generalizable analysis approach*** *for both the GC workflow and the HIT workflow. It is further hypothesized that the CS-AF can be adapted to other domains where technology-mediated collaborative workflow is required.*

CS-AF Analysis: Generalizability

The research goal for the CS-AF to be considered a "generalizable" approach for evaluating collaborative technology-mediated workflow is a tall order and somewhat beyond the scope of what can be validated with only two empirical studies. The research does, however, support the notion that the CS-AF could be a suggested framework that can be transformed for use in a variety of collaborative workflows where discrete steps leading to completion of a work task can be identified. The CS-AF is a complete methodology that was validated in two unique domains that proved to be transformable to each domain in a manner that the workflow metrics could be consistently reported and analyzed for meaningful result. To this extent, the H3 Hypothesis is proved to be valid; yet further use in other domains by other researchers is necessary to make any claims of generalizability beyond the suggestion that the framework could be transformed for use for collaborative workflow studies in other domains. The reach for generalizability is an iterative process that will take time; the goal is, however, extremely important and essential to the true realization of technology-mediated benefits in the eyes of the users and should be further pursued by researchers looking to advance technology adoption.

In order to accomplish the goals of ubiquitous computing and deliver collaborative human-computer interactive systems, a comparative evaluation of incremental improvements made through each technology-mediated transformation is important [14]. Kellogg et al. posit that success in HCI comes from "immersive understanding of the ever-evolving tasks and artifacts" [15:84]. Millen et al. state that understanding the context of the user environment and interaction is increasingly recognized as a key to new product innovation and good product design [123]. However, there is currently no widely-adopted generalizable model and methodology for conducting collaborative workflow analysis in a manner that addresses both the broad interdisciplinary view to provide a comparative analysis, and that includes critical qualitative and quantitative metrics. Lee and Payne suggest that "a new model is needed beyond the focus on 'work' or 'technology' to include rapidly increasing diversity of sociotechnical configurations" [17:179].

A need is apparent for a generalizable approach to evaluate collaborative technology-mediated workflow that focuses on a specific task to be done in a specific workflow – a model that incorporates a view at the current approach, compared to the enhanced approach as a result of the new technology. Arias et al. suggest that a shift to intended use or intended work versus. the computing system is necessary [18]. Baeza-Yates posits that future work should focus on the research method, the data collection, the data analysis, and the domain of study [19]. Plowman, Rogers, and Ramage add that designers might attend to the "work" of the setting, as well as the interactional methods or practices of the members as the work is being performed. The "job of work" in the "work of a setting" are the actions and interactions that inhabit and animate the work setting [20], [21].

The aim of this research is to introduce and exercise a consistent and structural methodology to capture and evaluate the individual human collaborative experience and collective experiences of collaborative individuals in a specific and targeted workflow (CS-AF). The technology-mediated impact on the individual is equally as important as is the overall technology-mediated impact on groups in the organization; the re-engineered workflow needs to be recorded, evaluated, and analyzed (in comparison to the existing workflow) in order to portray an accurate view of potential gains and gaps associated with the transformation.

The initial use of the CS-AF for the GC workflow produced consistent data, yet analysis based on means data at the determinant-level lacked the statistical precision to quantify variances in the comparison statistically. Expansion of the CS-AF analysis methodology using rANOVA, paired t-test, and CS-AF Summary Scorecard, added the rigor necessary to appropriately assess the gains and gaps between the workflows test for the HIT workflow study. The research has proved that the carefully selected cross-disciplinary elements of the CS-AF present an effective method for evaluation and comparison of collaborative workflows. The CS-AF facilitated a structured and replicable process for the collection and analysis of a diverse set of evaluation metrics between the current-state and technology-mediated workflows. The CS-AF analysis methodology delivered a useful analysis and evaluation that enabled both qualitative and quantitative perspectives of the gains and gaps associated with collaborative workflow studied.

	Primary Hypothesis Description H3	**GC WF**	**HIT WF**
		False	Valid
H_0 Null Hypothesis μBLWF = μTMWF	The CS-AF does not deliver a cross-disciplinary set of metrics that can be effectively transformed as a generalizable approach to evaluate collaborative technology mediated workflows.	False	
H_a Alternative Hypothesis μBLWF != μTMWF	The CS-AF does deliver a cross-disciplinary set of metrics that can be effectively transformed as a generalizable approach to evaluate collaborative technology mediated workflows.		Valid

The research displayed the adaptive nature of the CS-AF to enable transformation for use in two distinct different domains (GC and HIT). Transformation of the CS-AF survey instrument specific to the workflow steps in a targeted workflow is intended to aim each CS-AF empirical study instance directly at the specific workflow steps that are uniquely associated with the domain of study. The novel cross-disciplinary approach of the CS-AF and the unique adaptability of the CS-AF methodology to various domains suggest that this approach and analysis methodology can be transformed for generalized use with appropriate transformation of the CS-AF survey instrument.

6.2. Contributions to Knowledge

The novel works and contributions associated with the research conducted during this dissertation are stated below.

- Collaborative Space-Analysis Framework (CS-AF):
  - Investigation, distillation, and integration of key cross-disciplinary models and methods to evaluate technology-mediated collaborative workflow
  - Development of a transformable cross-disciplinary CS-AF approach that can be generalized to evaluate technology-mediated collaborative workflow, including qualitative and quantitative survey instrumental and evaluation metrics, and a field deployment methodology that can be adapted to unique domains
    - Integration of related works to form a cross-disciplinary approach
    - Customizability of field study approach and survey instrument
    - Statistical evaluation methodology and summary data scorecards

- Deployment, deployment, and analysis of two empirical field studies to test the CS-AF; conducting workflow analysis, development, implementation, evaluation, and analysis of both current-state and technology-mediated workflows:
  - GC Collaborative Workflow: Sales Order Process: technology-mediated workflow process, dynamic forms prototype, software/user interface design, architecture, and development
  - HIT Collaborative Workflow: Hypertension Exam: Wise&Well – Hypertension Exam App; user experience, system messages and wellness content, software design, architecture, development, technology-mediated workflow process, database, and device integration with Omron blood pressure monitor

6.3. Limitations

The analysis of collaborate workflows is a broad and complex topic that poses a variety of challenges, most significant of which are the selection of evaluation metrics and the deployment of those metrics in live field work. The CS-AF approach was to aim for a balance between parsimonious and comprehensive. One of the objectives of this research was to integrate cross-disciplinary evaluation methods into an approach that could be effective for evaluating collaborative workflows. The CS-AF has achieved that goal with refinements over the course of two empirical studies. The CS-AF methodology and analysis approach was effective in portraying the gains and gaps in the collaborative workflow's studies from five elements in a manner that could be meaningfully evaluated and reported. The CS-AF was expanded to be more robust through the second empirical study, incorporating statistical methods and analysis, and including a summary scorecard of the pre-post workflow datasets in a formalized and replicable process. The difficulty with this type of cross-disciplinary workflow analysis is managing the complexity of the framework while attempting appropriate levels of rigor and analysis. The CS-AF approach is a balance between a parsimony and completeness.

The research was somewhat limited in the sample size of the GC and HIT workflows studied, the number of participants, and the field study time duration. The GC workflow involved five participants from a workflow in a small company setting, and the HIT workflow involved 50 participants, which was the statistically minimal number required. Since the initial GC workflow was somewhat of a pilot study, the limitations were more associated with the small number of participants involved and the newness of the analysis methodology. The GC workflow was, however, instrumental in testing the validity of the CS-AF approach and identifying specific limitation with the statistical methodology in a way that could be addressed later with the HIT workflow study.

Incorporating more participants for a longer period of time, with perhaps multiple check points, would provide a long-term view and potentially more information for the HIT workflow study. Because of the coronavirus pandemic, all semi-structured sessions were covered via video conference, which was somewhat of a communications barrier with respect to typical interactivity that would happen in a face-to-face setting. Self-reporting of BP exam timing could pose some inconsistency in reporting; however, the baseline data was quite similar between the two independent groups for BP exam timings.

In retrospect, there were too many subjective questions (15 total) for 50 participants across two surveys (1500 responses). The analysis of the subjective questions was cumbersome and time-consuming, yet the themes extracted from these questions were very complementary to the statistical analysis of the survey questions. Refinement of the subjective questions to 1-2 questions per section would mostly like be just as meaningful and certainly more manageable. Refinements to the number of questions in the CS-AF instrument could also be a limitation, as the survey required participants to be captive for 20 minutes +/- and presented 104 questions across the 5 sections of the CS-AF in total. Further research into the minimal number of specific questions that can be asked for each metric would be a valuable exercise to investigate how the survey questions could be optimized, while still being robust enough to portray the necessary participant data.

Additionally, for the HIT workflow, expanded support from the clinician team for the alternate workflow experiences would be more beneficial to participants. The support for the alternative workflow was delivered by this researcher and, although responsive, may not have been excepted as well had the support come from the same clinical team. This approach would suggest a Beta period with the clinical team prior to engaging in the study, which would train and empower the clinical team to continue on as the main stream of support for patients as per the baseline workflow.

Chapter 7

Conclusion and Future Work

7.1 Conclusion

The development and integration of technology for collaborative workflows introduces many variables that are of great concern to companies, organization, and individuals. These variables include the costs of development, the switching cost associated with migrating from the current workflow to the technology-enhanced workflow, and details of how the technology-mediated workflow functions, compared to the current workflow. There is however, no consistent approach to evaluate and compare an existing workflow with the technology-mediated workflow enhancements in a manner that identifies the improvements (gains) and barriers (gaps) in replicable qualitative and quantitative measures. The three primary objectives of this research are targeted to address this problem: (1) to investigate cross-disciplinary related works to determine a functional and comprehensive approach to evaluate collaborative technology-mediated workflows, (2) to develop a field implementation and evaluation methodology, and test that framework through two diverse empirical studies, and (3) to formalize the "approach" into a replicable and generalizable framework that can be transformed for use in multiple domains.

Investigation of related works established a compass setting in four key domains where formal methods and existing practices for the evaluation of collaborative technology-mediated workflow originated. The research shows that historic works in Behavior Sciences, connected with “attitude to use” and “behavioral intent,” are essential aspects needed to evaluate workflow adoption. Prior research in technology-adoption from the Organizational Management domain provide rich examples of many models and empirical studies, developed over decades and focused on the analysis of “how and why” people adopt various technologies and what are the key determinants associated observing adoption. Similarly, the HCS/CSCW domain also has decades of research in cooperative and collaborative behavior, with a wide variety of models, approaches, and representative field studies looking into the context of adoption and evaluation of task-level acceptance of new technologies, amongst other related works. Finally, the Industrial Engineering domain also has historic participation in this space, with models and field investigation approaches tailored at quantifying process improvement and driving workflow optimization of new technology in commercial applications. The unique process of Value Stream Mapping is used in the CS-AF as means to define the workflow steps and a method for collecting workflow specific time-series data. Each of these domains has pivotal works that have been refined over years to uncover valuable insights from the perspective of each domain. This research compiles together key ingredients from these four domains to construct the Collaborative Space-Analysis Framework (CS-AF) in efforts to formulate an evaluation framework that delivers an integrated cross-disciplinary view of a current workflow compared with a technology-mediated collaborative workflow.

The research formalizes the CS-AF approach with an initial empirical study in the Graphic Communication (GC) domain with a pilot program to test the concept. In the GC workflow study, implementation of the CS-AF field methodology was put to practice, including a workflow assessment, workflow development/deployment of a technology-mediated solution, the implementation of the CS-AF survey instrument, data collection and analysis, and summary observations. The results of the GC workflow study validated the approach and helped to refine the CS-AF process, statistical analysis, and reporting towards a more replicable methodology. The second empirical study in Health Information Technology (HIT) workflow, specifically the hypertension exam workflow, was performed with 50 patient-participants, a clinician team, and a comprehensive workflow transformation towards a remote-asynchronous telehealth technology-mediated solution. The HIT workflow study also included a workflow assessment, baseline workflow analysis, development/deployment of the technology solution, and a second workflow analysis, followed by data collection, analysis, and reporting. Completion of the hypertension exam workflow enabled a more tightly defined field methodology for the CS-AF, statistical analysis and summary reporting procedures. The practical application of the theoretical concepts in the CS-AF in two empirical studies was instrumental in testing, assessing, and refining the CS-AF approach for more generalizable use.

The CS-AF and field methodology are grounded in the specific workflow steps necessary for target users to perform their work tasks. The CS-AF is adapted to the target workflow by incorporating the specific workflow steps for the workflow into the analysis framework, such that the CS-AF survey questions are specific to that targeted workflow. This adaptive approach of the CS-AF allows the researcher to transform the CS-AF in a tailored manner for the target workflow in a particular domain. The CS-AF survey data is then recorded for the formal workflow steps in the baseline workflow and then again following the technology-mediated solution for a true comparison on all CS-AF determinants between the pre- and post-workflows.

The CS-AF incorporates quantitative time-series data for each step in the workflows studied, Likert-scale comparisons for all CS-AF determinates (evaluation of means, between and within groups) and specific subjective questions for each of the five sections of the CS-AF. The cross-disciplinary and mixed-methods approach of the CS-AF combines quantitative and qualitative data, enabling a broad and diverse comparisons of technology-mediated collaborative workflows. The ability to transform the CS-AF survey instrument to the target workflow allows for a flexible and replicable approach that can be used for technology-mediated workflow evaluations in a variety of different domains.

7.2 Future Work

This research was targeted specifically at the telehealth domain with the anticipation that dramatic technology transformations are on the horizon with respect to emerging demand for remote-asynchronous telehealth solutions. The entire HIT segment is in the midst of similar digital transformation that has revolutionized the communications industry, now that the underlying technologies have been somewhat vetted in workflows that are not as risky as they are in HIT. Conducting this research in the midst of a global pandemic has accelerated the need for future work in the HIT domain for further investigation in technology-mediated doctor-patient collaborative workflows, including immediate adjacencies associated with this specific research, and from an extended perspective in collaborative telehealth workflows, both in breadth and depth of this emerging domain. Future work should also be aimed at the vision for the telehealth domain with forward-thinking perspectives that anticipate unmet needs in this changing terrain. In addition, opportunities for future work beyond the scope of telehealth/HIT exist in other domains that exhibit similar transformation in collaborated technology-mediated workflow.

Adjacent research opportunities in Telehealth

Immediate opportunities for future research exist in several adjacent areas that percolated as direct result of this specific research. Two of these areas are the accessibility of the user interface/experience and a focus on the effect that age has on collaborative technology-mediated adoption.

Findings from this research indicated that there is an adoption hurdle with technology-mediated workflows, specifically in the areas of ease of use and ease of learning. The results indicate that, although the Wise & Well app was fully functional, specific gaps exist in the accessibility of the user experience for the initial install and onboarding of the app, and with the interaction with the Omron BP device via Bluetooth mode. These issues present an opportunity to further investigate the association and possible barriers in UI/UX accessibility of mobile apps for telehealth.

The topic of UI/UX accessibility of mobile apps has been widely researched with accessibility guidelines from major software publishers (such as Google, Apple, etc.) and associations (such as W3C); however, research suggests that these guidelines are not sufficient to ensure that developers of telehealth apps have detailed design direction to align with accessibility gaps. Researchers Ross et al. posit that a host of intrinsic and extrinsic factors need to be considered when designing technology for telehealth [217]. The researchers further suggest that an epidemiology-based view, similar to the CS-AF workflow-stage approach, is needed and that more extensive field research is needed to test accessibility approaches that align with users [217].

Ballantyne et al.'s research distills accessibility guidelines from multiple sources, such as W3C's WCAG 2.0 guidelines, and suggest that even these comprehensive guidelines fall short with respect to uncovering a full breadth of accessibility parameters. The researchers further posit that accessibility should include a focus on the design, system, and content levels to ensure that apps are perceivable, operable, understandable, and robust to users [218]. Yan et al.'s research suggests that future research is needed to establish automated baseline accessibility tests that can be used to define a minimum acceptable boundary condition for mobile app accessibility [219]. The research identifies the vital importance of accessibility testing and complexity of such testing in terms of selection of the wide-range of test determinants that are representative of the diverse needs of the general population.

Further research is needed in the area of accessibility using mobile apps for telehealth. Opportunities exist to build of off extensive research in accessibility, both in mobile apps and in telehealth. With telehealth in its infancy, accessibility research in consumer electronics apps using mobile technology can used with proven accessibly guidelines for web-based apps as a foundational guide to accessibility testing approaches for mobile-based telehealth apps [220]. Researcher Therese Fessenden posits that investigating, implementing, and testing accessibility features can build trust and facilitate a path to better accessibility [221], Langer et. al, [222].

Further exploration in the area of accessibility is a natural step for future research that is immediately adjacent to this research. Specific analysis of complementary accessibility determinates that could be complement the CS-AF, and ultimately be field tested, would be of high importance to investigate the gaps in ease of use, ease of learning, and attitude and behavior to use. Research Raluca Budiu states that mobile apps need to be designed specifically for "mobile," with respect to content and accessibility features, not be just a copy of the website to an app [223]. Consideration of the "mobile platform" as a unique environment and mobile apps as unique instantiations versus a repeat of the website is critical and underscores the importance for a unique set of accessibility test metrics to evaluate mobile apps. Future research should focus on the specific accessibility metrics for mobile apps that are designed for telehealth.

Another important area for future work adjacent to this research is the exploration of technology-mediated adoption for the elderly. Results from this research indicate that age is a key variable when considering the design requirements for technologies that is intended for use with populations that might not be tech-savvy. This is a significant issue specific for telehealth, since remote asynchronous workflows may not be initially appropriate for elderly patients who are not tech-savvy. Technology adoption of the elderly is a prime target for future work, since this population is often the very target population for telehealth workflows.

Elderly test participants in this study were not familiar with Bluetooth (BT) technology, nor with downloading and installing custom mobile apps, as indicated by low ratings for ease of learning and ease of use. Subjective comments voiced from individuals over 50 years old targeted specific areas of complexity, including the app's download, install, registration, and BT device-paring. Conversely, participants under the age of 30 were able to download, install, register, and BT-pair the device without even reading any of the instructions. It is clear that there is a "digital divide" with respect to age that needs to be explored further.

Researchers Knowles and Hanson investigated technology adoption in the elderly; their primary research suggests that the older adults "are often unwilling to acknowledge that their lives would be enriched through digital technologies, whether or not they were made accessible" [224:73]. This resistance to adoption observation made by Knowles and Hanson is associated with "attitude and behavior", and it was also identified as a key finding of this hypertension exam workflow study. Further research is needed in the area of attitude and behavioral, specifically regarding the "intent to use" new technologies with the older populations. The hypertension exam workflow study indicated that for attitude and behavior to improve, participants need to internalize a "relative advantage", and as stated by Knowles and Hanson, this needs to be addressed, even prior to important accessibility concerns. The researchers go further to state that resistance to technology by older populations is deeply rooted in their comfort, trust, and confidence in analog approaches, versus high-tech options, which they feel are unrewarding, risky, and confusing. Contributing to the negative attitude to adopt technology by the elderly are three factors identified by the researchers: responsibility, values, and cultural expectations [224], [225]. Future research needs to focus on the factors that affect attitude (including managing risk, discovering a relative advantage, and managing cultural expectations), as the highest priority – even in advance of important accessibility concerns.

Future investigation into the models, methods, metrics, etc. necessary to uncover attitude and behavior toward telehealth technology adoption in older populations is required. Attitude and behavior research focused on mobile app adoption is on the rise, and investigation into the various attitudinal determinates used to evaluate technology adoption is needed. Analysis of research in HCI/CSCW and the Social Sciences (e.g., Ajzen [67], [67], [68]) is necessary to distill the specific approach needed to address the adoption gaps that have been identified; following this analysis, additional field work to test the approach will be needed.

Extended research in collaborative telehealth workflows (breadth and depth)

From a breadth perspective, future work across all vital telehealth workflows is essential. Understanding the idiosyncrasies of telehealth adoption for other specific symptomatic collaborative workflows (such as diabetes, asthma, mental health, skin, cancer, colds, allergies, migraines, and endocrine, cardiovascular, pulmonary, and gastrointestinal issues) are candidate workflows to study. In Dorsey and Topol's State of Telehealth research, they posit that a comprehensive view of telehealth workflows, including the doctor/patient experience, is needed to enable further adoption [216]. The research goes on to suggest that better understanding of the desired outcomes and ways to bridge the digital divide are needed for mass adoption to occur. Future research that investigates similar technology-mediated workflows in telehealth (e.g., personal micro sensing device integrated with smartphone app) is important to evaluate whether the findings in this study are unique to hypertension exam workflow or are indicative of other similar telehealth workflows.

Expansion into the depth of specific telehealth workflows (in their entirety) should be conducted; these workflows include those for specific conditions, end-to-end, involving all aspects of the workflow from provider or clinical team, to the patient [EHR], to insurance [MIS billing system], and so on. For example, participants from this hypertension exam workflow study felt that technology could improve the front-end of the workflow (e.g., scheduling appointments, registration, etc.). There is a need for future research to go deep into an ongoing telehealth workflow, collecting data over an extending time interval in order to gain a more longitudinal view of the gains and gaps in the workflow using the CS-AF. Studies of this detail and rigor are few, but are in demand; as stated by Dorsey et al., “Rigorous randomized, controlled trials of telehealth interventions that show improvements in care or health have been few” [213]. Telehealth is in its infancy, and many of the technologies are prime for adoption; however, barriers to adoption need to be uncovered through collaborative technology-mediated workflow research that will illuminate the gaps that need to be bridged and will highlight the gains that can be leveraged.

Research aimed at the future vision for collaborative workflow in telehealth

An acceleration of telehealth technology migration has come as a direct result of demand for remote/asynchronous workflows forced during the COVID-19 pandemic. Future investigation is needed to determine whether recent advancements in telehealth with persist and become the “new normal”. Or will we drift back to traditional workflows? Future research directed at the “future space” for telehealth is also needed to help test conceptual, forward-looking views of the potentially more tightly integrated and accessible futuristic workflows for the telehealth domain. What the future of telehealth will look like and how the patient/doctor collaboration will advance beyond current barriers need further investigation.

Researcher Haque posits that technology used during the pandemic may not be appropriate for long-term use/care, and that clinicians and patients will need to determine what specific remote care will be followed post-pandemic. The research continues to state that the technologies and services offered during the pandemic may have been implemented and adopted as a result of necessity, and not out of preference [226]. Future research in telehealth workflow is needed to evaluate those remote/asynchronous workflows that were adopted during the pandemic to uncover patients' perspectives regarding what they liked and disliked, as well as their attitudes toward future use. There is an immediate and time-sensitive need to conduct this post-pandemic perspective of patients while the imposed workflows are still in use or in recent memory. This type of future research could be extremely beneficial toward understanding users' perspective of critical accessibility barriers to adoption for future telehealth workflows.

As technology permeates the healthcare domain from various avenues (including consumer mobile electronics, advanced cloud-computing, micro-devices, etc.), a new vision for healthcare will evolve that integrates the traditional on-site services with complementary remote-asynchronous services that involve a fluid balance of supported self-care and clinician care. Future research focused on the exploration of the future vision for healthcare is essential. Research is needed to determine the existing gaps in continuity of service for patients that is technology enabled, such as the social-technical digital divide, technical competency, clinician support and patient training, and data integration, amongst others. A comprehensive taxonomy of the future domain will need to be researched, defined, and vetted to ensure that the design of future systems address all concerns. In their research Telemedicine: A New Health Care Delivery System, Bashshur et al. posit that research must continue to identify critical objectives, problems, and impediments, including research strategies and methodologies to advance telehealth. The researchers continue stating that future vision for telehealth should be researched using a framework (e.g., CS-AF), with a matrix on the cost and quality of the complete ecosystem for both patients and providers [227]. The future of healthcare is largely a social-technical dilemma that will require iterative empirical studies based on a replicable framework in order to truly define the space for all stakeholders involved.

Transformative collaborated technology-mediated workflow in other domains

The CS-AF can also be adapted for collaborative workflow research in other domains where technology-mediated solutions are emerging. The CS-AF approach can be easily transformed for other collaborative workflows that are work-task oriented. Future research can be directed in the packaging domain to help remote shoppers better investigate final purchases for items that are hand-selected, such as fruit. The manufacturing sector is under constant improvement seeking workflow optimization; future research could expand into this domain as a method to investigate and direct continuous improvement. The transportation and logistics domain are being revolutionized by technology for both B2B and B2C workflows; this sector is another area that could benefit from future research to optimize collaborative workflows. Higher Education is under siege with the recent pandemic and the increased cost of education; there is an urgent need to deliver remote/asynchronous collaborative workflows that emulate the experience of face-to-face instruction. The Higher Education sector could also be a target for future work using the CS-AF as a means to capture the current approach and to evaluate technology-mediated improvements.

Research aimed at further refinement and reconciliation of the CS-AF

Underscoring the need for a method like the CS-AF to prevail as a best practice, the opportunities for future research using the CS-AF are vast. Future research should also be directed to further testing and refinement of the CS-AF, such that the survey instruments, field engagement methodology, and statistical analysis and reporting elements are further streamlined. Additionally, future research can be targeted at reconciling the CS-AF approach with the specific cross-disciplinary domains (HIT, CSCW/HCI, Social Sciences, Industrial Engineering, and Organizational Management) that were used for the formation of the CS-AF. Future research can be directed at identifying the contributions from each domain towards the integrated CS-AF approach for a potentially more comprehensive evaluation using this integrated approach.

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Appendices

Appendix A

CS-AF Survey Instrument

The following CS-AF survey is approved by the RIT IRB for field use with test participants for the Hypertension Collaborative Workflow empirical study.

Collaborative Space – Analysis Framework Survey
Hypertension Workflow

CONTEXT: What is the Context of your workflow (circle one)?

1. **Synchronicity:** concerns a continuum of coordinated action ranging from being conducted synchronously (same time), to asynchronously, (different times).

1	2	3	4	5	6	7

Asynchronous (different times) — Mixed (both) — Synchronous (same time)

2. **Physical Distribution:** concerned with location of the workflow.

1	2	3	4	5	6	7

Same Location — Mixed — Different Location

3. **Participants:** concerned with number of people (scale) involved in the workflow.

1	2	3	4	5	6	7 or more

Person — Persons

4. **Communities of Practice**:

1	2	3	4	5	6	7 or more

Department — Departments

5. **Nascence:** (coming into being): un-established (e.g. new) versus established (e.g. old) coordinated actions".

1	2	3	4	5	6	7

Routine (established) — developing (coming into being) — New (un-established)

6. **Planned Permanence:** whether the collaboration is intended to be short-term or long-term.

1	2	3	4	5	6	7

Short-term (1-3 months) — mid-term (6-12 month) — Long-term (+ 18 months)

7. **Turnover:** refers to the rapidity with which participants enter and leave the workflow".

1	2	3	4	5	6	7

Low (same people) — medium (new people monthly) — High (new people daily)

Does this workflow require you to be physically present?

____

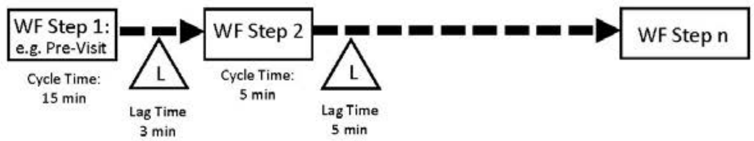
Do you considered this workflow to be a new experience or a familiar experience?

____

CS-AF HT Survey 1

PROCESS: For "process" we measure the "**time**" (cycle-time; time required to complete one workflow step and lag-time; time lapse between the completion of one workflow step and the start of the next step in the workflow) associated with the workflow and the "**quality**" of information associated with each stage of the workflow.
Process Time (PT): Identify the time associated with each step in the current-state workflow.

1. What is the cycle-time and lag-time required to complete each segment of the workflow?



Enter the cycle-time and lag-time for the Current-State Workflow and enter a suggested acceptable time for each.

Current-state hypertension workflow steps											
1. Pre-Visit Contact Dr.'s office and schedule appt.		**2. Register** Travel to Dr.'s office and check-in		**3. Exam** Part 1: Nurse/Patient to conduct BP reading		**3. Exam** Part 2: Dr. to conduct exam		**4. Treatment** Dr. to prescribe/ perform treatment		**5. Post-Exam** Follow-up with Nurse, Admin, or Specialist, Pharmacy	
Current-state workflow time assessment (minutes/seconds):											
Cycle Time	Lag Time	Cycle Time	Lag Time	Cycle Time	Lag Time	Cycle Time	Lag Time	Cycle Time	Lag Time	Cycle Time	Lag Time

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Internal use (do not fill out the section below).

Total Cycle Time:________________

Total Lag Time:_________________

Total Workflow Time:_____________

CS-AF Survey Instrument (page 3 of 12):

2. Rate the **cycle/lag time** for each of the following steps in the workflow by circling the number that best represents your rating. For "cycle-time" is the time required to complete one workflow step and "lag-time" is the lapse time between the completion of one workflow step and the start of the next step in the workflow.

Cycle Time	Very Unacceptable	Unacceptable	Slightly Unacceptable	Neither Acceptable nor Unacceptable	Slightly Acceptable	Acceptable	Very Acceptable
1. **Pre-Visit** Contact Dr.'s office and schedule appt.	1	2	3	4	5	6	7
2. **Register** Travel to Dr.'s office and check-in	1	2	3	4	5	6	7
3. **Exam** Part 1: Nurse/Patient to conduct BP reading	1	2	3	4	5	6	7
4. **Exam** Part 2: Dr. to conduct exam	1	2	3	4	5	6	7
5. **Treatment** Dr. to prescribe/ perform treatment	1	2	3	4	5	6	7
6. **Post-Exam** Follow-up with Nurse, Admin, or Specialist, Pharmacy	1	2	3	4	5	6	7
Lag Time	Very Unacceptable	Unacceptable	Slightly Unacceptable	Neither Acceptable nor Unacceptable	Slightly Acceptable	Acceptable	Very Acceptable
1. **Pre-Visit** Contact Dr.'s office and schedule appt.	1	2	3	4	5	6	7
2. **Register** Travel to Dr.'s office and check-in	1	2	3	4	5	6	7
3. **Exam** Part 1: Nurse/Patient to conduct BP reading	1	2	3	4	5	6	7
4. **Exam** Part 2: Dr. to conduct exam	1	2	3	4	5	6	7
5. **Treatment** Dr. to prescribe/ perform treatment	1	2	3	4	5	6	7
6. **Post-Exam** Follow-up with Nurse, Admin, or Specialist, Pharmacy	1	2	3	4	5	6	7

Is there a part of the workflow that seemed like a waste of time, elaborate?

Is there a part of the workflow that seemed confusing (poor instructions, not intuitive)?

Process Quality (PQ): The next two questions are concerned with the quality of the information at each stage of the workflow, specifically, how important (relevant) is the information and how accurate is the information you receive.

1. *How relevant is the **information quality** at each step in the workflow?*

How relevant is the info.	Very Irrelevant	Irrelevant	Slightly Irrelevant	Neither Relevant nor Irrelevant	Slightly Relevant	Relevant	Very Relevant
1. **Pre-Visit** Contact Dr.'s office and schedule appt.	1	2	3	4	5	6	7
2. **Register** Travel to Dr.'s office and check-in	1	2	3	4	5	6	7
3. **Exam** Part 1: Nurse/Patient to conduct BP reading	1	2	3	4	5	6	7
4. **Exam** Part 2: Dr. to conduct exam	1	2	3	4	5	6	7
5. **Treatment** Dr. to prescribe/ perform treatment	1	2	3	4	5	6	7
6. **Post-Exam** Follow-up with Nurse, Admin, or Specialist, Pharmacy	1	2	3	4	5	6	7

2. *How important is the **information quality** at each step in the workflow?*

How important is the info.	Very Unimportant	Unimportant	Slightly Unimportant	Neither Important nor Unimportant	Slightly Important	Important	Very Important
1. **Pre-Visit** Contact Dr.'s office and schedule appt.	1	2	3	4	5	6	7
2. **Register** Travel to Dr.'s office and check-in	1	2	3	4	5	6	7
3. **Exam** Part 1: Nurse/Patient to conduct BP reading	1	2	3	4	5	6	7
4. **Exam** Part 2: Dr. to conduct exam	1	2	3	4	5	6	7
5. **Treatment** Dr. to prescribe/ perform treatment	1	2	3	4	5	6	7
6. **Post-Exam** Follow-up with Nurse, Admin, or Specialist, Pharmacy	1	2	3	4	5	6	7

Do you feel there is an opportunity to reduce the time associated with this workflow?

____

Do you feel there is an opportunity to enhance the information quality for this workflow?

____

CS-AF Survey Instrument (page 5 of 12):

TECHNOLOGY: In this section you will provide insights regarding the technology incorporated in the workflow; does the technology incorporated in the workflow provide "usefulness" and/or "ease-of-use"? (TAM, Davis, 1989)

Perceived Usefulness (PU): *Enhance workflow Performance*

1. *How **useful** is the technology that is incorporated in each step of the current workflow to you?*

Useful	Very Useless	Useless	Slightly Useless	Neither Useful nor Useless	Slightly Useful	Useful	Very Useful
1. **Pre-Visit** Contact Dr.'s office and schedule appt.	1	2	3	4	5	6	7
2. **Register** Travel to Dr.'s office and check-in	1	2	3	4	5	6	7
3. **Exam** Part 1: Nurse/Patient to conduct BP reading	1	2	3	4	5	6	7
4. **Exam** Part 2: Dr. to conduct exam	1	2	3	4	5	6	7
5. **Treatment** Dr. to prescribe/ perform treatment	1	2	3	4	5	6	7
6. **Post-Exam** Follow-up with Nurse, Admin, or Specialist, Pharmacy	1	2	3	4	5	6	7

2. *Do you feel technology enhancements can improve the usefulness for each step of the workflow?*

Technology enhanced Usefulness	Very Unlikely	Unlikely	Slightly Unlikely	Neither Likely nor Unlikely	Slightly Likely	Likely	Very Likely
1. **Pre-Visit** Contact Dr.'s office and schedule appt.	1	2	3	4	5	6	7
2. **Register** Travel to Dr.'s office and check-in	1	2	3	4	5	6	7
3. **Exam** Part 1: Nurse/Patient to conduct BP reading	1	2	3	4	5	6	7
4. **Exam** Part 2: Dr. to conduct exam	1	2	3	4	5	6	7
5. **Treatment** Dr. to prescribe/ perform treatment	1	2	3	4	5	6	7
6. **Post-Exam** Follow-up with Nurse, Admin, or Specialist, Pharmacy	1	2	3	4	5	6	7

Is there a particular step in the workflow that seemed difficult to use? elaborate?

____

Perceived Ease-of-Use (PEU): *Freedom from Effort*

3. *How **easy-to-use** is the technology that is incorporated in each step of the current workflow to you?*

Easy-to-Use	Very Difficult to Use	Difficult to Use	Slightly Difficult to Use	Neither Easy nor Difficult to Use	Slightly Easy to Use	Easy to Use	Very Easy to Use
1. **Pre-Visit** Contact Dr.'s office and schedule appt.	1	2	3	4	5	6	7
2. **Register** Travel to Dr.'s office and check-in	1	2	3	4	5	6	7
3. **Exam** Part 1: Nurse/Patient to conduct BP reading	1	2	3	4	5	6	7
4. **Exam** Part 2: Dr. to conduct exam	1	2	3	4	5	6	7
5. **Treatment** Dr. to prescribe/ perform treatment	1	2	3	4	5	6	7
6. **Post-Exam** Follow-up with Nurse, Admin, or Specialist, Pharmacy	1	2	3	4	5	6	7

4. *Do you feel technology enhancements can improve the **ease-of-use** for each step of the workflow?*

Technology enhanced Ease of Use	Very Unlikely	Unlikely	Slightly Unlikely	Neither Likely nor Unlikely	Slightly Likely	Likely	Very Likely
1. **Pre-Visit** Contact Dr.'s office and schedule appt.	1	2	3	4	5	6	7
2. **Register** Travel to Dr.'s office and check-in	1	2	3	4	5	6	7
3. **Exam** Part 1: Nurse/Patient to conduct BP reading	1	2	3	4	5	6	7
4. **Exam** Part 2: Dr. to conduct exam	1	2	3	4	5	6	7
5. **Treatment** Dr. to prescribe/ perform treatment	1	2	3	4	5	6	7
6. **Post-Exam** Follow-up with Nurse, Admin, or Specialist, Pharmacy	1	2	3	4	5	6	7

Do you believe that this workflow is effective for you to accomplish your goal? elaborate?

____

CS-AF Survey Instrument (page 7 of 12):

U.S.E. Usefulness, Satisfaction, and Ease-of-Use Questionnaire:

The Usefulness, Satisfaction, and Ease-of-Use Questionnaire (USE) includes a series of positive statements (e.g., "I would recommend it to a friend"), to which you will rate your level of agreement on a 7-point (Likert) scale. These statements are used to gauge your confidence in the blood pressure workflow system used. Circle a number associated with each statement for the blood pressure workflow process that best indicates your rating for this workflow.

- **Usefulness:** (defined as; effective, productive, makes things I want to accomplish easier, saves time)

It helps me be more effective.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

It helps me be more productive.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

It is useful.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

It gives me more control over the activities in my life.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

It makes the things I want to accomplish easier to get done.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

It saves me time when I use it.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

It meets my needs.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

It does everything I would expect it to do.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

CS-AF Survey Instrument (page 8 of 12):

- **Ease-of-Use:** (Ease of Use is defined as; simple, user friendly, flexible, effortless, streamlined)

It is easy to use.

1	2	3	4	5	6	7

Strongly Disagree Strongly Agree

It is simple to use.

1	2	3	4	5	6	7

Strongly Disagree Strongly Agree

It is user friendly.

1	2	3	4	5	6	7

Strongly Disagree Strongly Agree

It requires the fewest steps possible to accomplish what I want to do with it.

1	2	3	4	5	6	7

Strongly Disagree Strongly Agree

It is flexible.

1	2	3	4	5	6	7

Strongly Disagree Strongly Agree

Using it is effortless.

1	2	3	4	5	6	7

Strongly Disagree Strongly Agree

I can use it without written instructions.

1	2	3	4	5	6	7

Strongly Disagree Strongly Agree

I don't notice any inconsistencies as I use it.

1	2	3	4	5	6	7

Strongly Disagree Strongly Agree

Both occasional and regular users would like it.

1	2	3	4	5	6	7

Strongly Disagree Strongly Agree

I can recover from mistakes quickly and easily.

1	2	3	4	5	6	7

Strongly Disagree Strongly Agree

I can use it successfully every time.

1	2	3	4	5	6	7

Strongly Disagree Strongly Agree

CS-AF Survey Instrument (page 9 of 12):

- **Ease of Learning:** (defined as; quickly became skillful with it, remembered how to use it, easy to learn to use it)

I learned to use it quickly.

1	2	3	4	5	6	7

Strongly Disagree … Strongly Agree

I easily remember how to use it.

1	2	3	4	5	6	7

Strongly Disagree … Strongly Agree

It is easy to learn to use it.

1	2	3	4	5	6	7

Strongly Disagree … Strongly Agree

I quickly became skillful with it.

1	2	3	4	5	6	7

Strongly Disagree … Strongly Agree

- **Satisfaction:** (defined as; it works the way I want it to work, it is fun, wonderful, I would recommend it to a colleague, pleasant to use, and I feel I need to have it)

I am satisfied with it.

1	2	3	4	5	6	7

Strongly Disagree … Strongly Agree

I would recommend it to a friend.

1	2	3	4	5	6	7

Strongly Disagree … Strongly Agree

It is fun to use.

1	2	3	4	5	6	7

Strongly Disagree … Strongly Agree

It works the way I want it to work.

1	2	3	4	5	6	7

Strongly Disagree … Strongly Agree

It is wonderful.

1	2	3	4	5	6	7

Strongly Disagree … Strongly Agree

I feel I need to have it.

1	2	3	4	5	6	7

Strongly Disagree … Strongly Agree

It is pleasant to use.

1	2	3	4	5	6	7

Strongly Disagree … Strongly Agree

ATTITUDE (A): What is your attitude toward using the technology incorporated in the workflow?

1. A1: I have a positive opinion about the workflow.

Opinion about the workflow	Very Negative	Negative	Slightly Negative	Neither Positive nor Negative	Slightly Positive	Positive	Very Positive
	1	2	3	4	5	6	7

2. A2: I think using the workflow is good for me.

The workflow is good for me	Very Bad	Bad	Slightly Bad	Neither Good nor Bad	Slightly Good	Good	Very Good
	1	2	3	4	5	6	7

3. A3: I think using the workflow is appropriate for me.

The workflow is appropriate for me	Very Inappropriate	Inappropriate	Slightly Inappropriate	Neither Appropriate nor Inappropriate	Slightly Appropriate	Appropriate	Very Appropriate
	1	2	3	4	5	6	7

Do you feel satisfied with how you accomplished your task? elaborate?

BEHAVIOR (BI): What is your intention to use the workflow/technology?

1. BI1. I intend to use this workflow in next month.

Intent to use the workflow	Very Unlikely	Unlikely	Slightly Unlikely	Neither Likely nor Unlikely	Slightly Likely	Likely	Very Likely
	1	2	3	4	5	6	7

2. BI2. I expect my use of the workflow and will continue in the future.

Continue to use the workflow	Very Unlikely	Unlikely	Slightly Unlikely	Neither Likely nor Unlikely	Slightly Likely	Likely	Very Likely
	1	2	3	4	5	6	7

Did any part of this workflow frustrate you? elaborate?

Net Promoter Score (NPS):
Net Promoter Score (NPS) measures the customer experience with the workflow to determine how likely users are to promote the workflow to others in their circle of influence. Please rate the likelihood of promoting this workflow to a friend or college on a scale of 0 to 10, 0 being "Not at all likely" and 10 being "extremely likely".

How likely is it that you would recommend this workflow to a friend or colleague?

1	2	3	4	5	6	7	8	9	10

Not at all Likely Extremely Likely

CS-AF HT Survey 10

CS-AF Survey Instrument (page 11 of 12):

OUTCOMES:

Awareness (OA): information sharing and communications

1. *For each stage in the workflow, how **aware** do you feel people are of your goals?*

Others Aware of your Goals	Very Unaware	Unaware	Slightly Unaware	Neither Aware nor Unaware	Slightly Aware	Aware	Very Aware
1. **Pre-Visit** Contact Dr.'s office and schedule appt.	1	2	3	4	5	6	7
2. **Register** Travel to Dr.'s office and check-in	1	2	3	4	5	6	7
3. **Exam** Part 1: Nurse/Patient to conduct BP reading	1	2	3	4	5	6	7
4. **Exam** Part 2: Dr. to conduct exam	1	2	3	4	5	6	7
5. **Treatment** Dr. to prescribe/ perform treatment	1	2	3	4	5	6	7
6. **Post-Exam** Follow-up with Nurse, Admin, or Specialist, Pharmacy	1	2	3	4	5	6	7

Goal Alignment (OCG): is there a shared common ground

2. *How likely does the information **quality** meet your needs at each step in the workflow?*

Info meets your Needs	Very Unlikely	Unlikely	Slightly Unlikely	Neither Likely nor Unlikely	Slightly Likely	Likely	Very Likely
1. **Pre-Visit** Contact Dr.'s office and schedule appt.	1	2	3	4	5	6	7
2. **Register** Travel to Dr.'s office and check-in	1	2	3	4	5	6	7
3. **Exam** Part 1: Nurse/Patient to conduct BP reading	1	2	3	4	5	6	7
4. **Exam** Part 2: Dr. to conduct exam	1	2	3	4	5	6	7
5. **Treatment** Dr. to prescribe/ perform treatment	1	2	3	4	5	6	7
6. **Post-Exam** Follow-up with Nurse, Admin, or Specialist, Pharmacy	1	2	3	4	5	6	7

<<Qualitative Questions>>

CS-AF Survey Instrument (page 12 of 12):

Goal Alignment (OCG): is there a shared common ground

3. *What was your **primary goal** for this workflow?*

___

4. Do you have any **sub-goal**(s) for this workflow?

___

5. Were all your goals accomplished by this workflow, or are there unmet goals?

___

6. How **aligned** do you feel people are with your goals at each step of the workflow?

Others Aligned with your Goals	Very Misaligned	Misaligned	Slightly Misaligned	Neither Aligned nor Misaligned	Slightly Aligned	Aligned	Very Aligned
1. **Pre-Visit** Contact Dr.'s office and schedule appt.	1	2	3	4	5	6	7
2. **Register** Travel to Dr.'s office and check-in	1	2	3	4	5	6	7
3. **Exam** Part 1: Nurse/Patient to conduct BP reading	1	2	3	4	5	6	7
4. **Exam** Part 2: Dr. to conduct exam	1	2	3	4	5	6	7
5. **Treatment** Dr. to prescribe/ perform treatment	1	2	3	4	5	6	7
6. **Post-Exam** Follow-up with Nurse, Admin, or Specialist, Pharmacy	1	2	3	4	5	6	7

Appendix B

Institutional Review Board

This research was approved by the Institutional Review Board of the Rochester Institute of Technology. This Appendix includes the IRB Form C approval, Informed Consent (for participants), and the Research Abstract (for participants).

Subject: A Framework for Evaluating Technology-Mediated Collaborative Workflow – Hypertension Blood Pressure Workflow Example
Date: Friday, June 19, 2020 at 12:24:36 PM Eastern Daylight Time
From: Heather M Foti
To: Christopher Bondy
CC: Human Subjects Research Office

Hi Chris-

Your amendment for this project is approved and you can continue data collection.

You will need to modify the recruiting materials as discussed in my email from 6/16 to more closely match the intent of your project. Please send revised materials to hsro@rit.edu.

Heather

Heather M Foti, MPH
Associate Director
Human Subjects Research Office (HSRO)
Rochester Institute of Technology

R·I·T

Rochester Institute of Technology

RIT Institutional Review Board for the
Protection of Human Subjects in Research
141 Lomb Memorial Drive
Rochester, New York 14623-5604
Phone: 585-475-7673
Fax: 585-475-7990
Email: hmfsrs@rit.edu

Form C
IRB Decision Form
FWA# 00000731

TO: Christopher Bondy

FROM: RIT Institutional Review Board

DATE: **April 8, 2019**

RE: Decision of the RIT Institutional Review Board

Project Title – A Method for Exploring the association between Current-State and Enhanced Future-State Technology-Mediated Collaborative Workflow - Hypertension Workflow Example

HSRO # **05040319**

The Institutional Review Board (IRB) has taken the following action on your project named above.

☒ Exempt _46.104 (b) (3B)_

Now that your project is approved, you may proceed as you described in the Form A.

You are required to submit to the IRB any:

- **Proposed** modifications and wait for approval before implementing them,
- Unanticipated risks, and
- Actual injury to human subjects.

Heather Foti, MPH
Associate Director
Office of Human Subjects Research

Revised 08.17.2017

Rochester Institute of Technology
INFORMED CONSENT

Title of Study: *A Framework for Evaluating Technology-Mediated Collaborative Workflow – Hypertension Blood Pressure Workflow Example*

Principal Investigator: Christopher Bondy, Visiting Professor
Office: 585-475-2755 Mobile: 585-233-7035 email: cxbppr@rit.edu
Gannett 7B 1171, 69 Lomb Memorial Drive, Rochester, NY 14623

Faculty Advisor: Pengcheng Shi, PhD, Associate Dean for Research & Scholarship/PhD Program Director
Ph.D. Program in Computing and Information Sciences, Golisano College of Computing and Information Sciences

INTRODUCTION

You are invited to join a research study to evaluate the current "in-doctor's office" process for blood pressure readings compared to the use of new technology that enables remote blood pressure readings, either using a manual or an automated device with a smartphone at a time and place that is convenient to you. Please take whatever time you need to discuss the study with your family and friends, or anyone else you wish to. The decision to join, or not to join, is up to you.

In this research study, we are investigating/testing/comparing/evaluating the current workflow associated with blood pressure readings that are performed in your doctor's office and comparing that current approach with a portable blood pressure monitor and mobile app that can be used in an unsupervised manner, in the convenience of your home to conduct blood pressure readings multiple times of the day, at a time that you wish.

WHAT IS INVOLVED IN THE STUDY?

If you decide to participate in this study, this is a basic outline of what will happen over the course of your participation. Fifty (50) participants from a pool of hypertension/pre-hypertension patients will be selected for this study comprising of a minimum of 8 participants (4 male and 4 female) across 6 different age-bands (age bands: 18-24, 25-34, 35-44, 45-54, 55-59, +60). Each individual involved in this study will participate in two (2) identical face-to-face/video conference, semi-structured interviews that will be conducted, one at the beginning of the study and one at the end of the study. For this study, one-half of the study participants (2 male and 2 female across the 6 different age-bands) will be randomly selected to use a "new" system for blood pressure monitoring and will be provided with an FDA approved portable Omron blood pressure monitor and an iOS or Android blood pressure app. The other study participants will be provided a wrist-cuff blood pressure monitoring device and will be asked to record their blood pressure manually, twice daily, for 3 weeks on a paper form that will be provided. The technology enabled sub-group of participants will use the blood pressure device and mobile app twice-daily, for a minimum period of three weeks. Following the 3-week period all 50+/- study individuals will participate in a second semi-structure interview, via face-to-face or video conference, culminating the end of the study. Each of the semi-structured interviews (conducted at the start and end of the study will) take 30-45 minutes to complete. The specific questions covered in the semi-structured are highlighted below.

The objective of this study is to evaluate a comparison between the current "in-doctor's office" process for a blood pressure exam compared with a "new" technology-mediate approach using the remote BP device and the smartphone app or a manual wrist-cuff device. A second goal of the study is to validate the general use of the unique survey comparison methodology that has been developed for this study. The semi-structured interview will follow a consistent set of structured and unstructured (open-ended) questions that are organized in the following categories in the table below. A complete example survey that is representative of exactly what you will be asked can be provided for your further reference.

Semi-structured Survey Questions/Parameters	
The blood pressure workflow (WF) will be assessed based on nine (9) different parameters listed below. Structured questions will be recorded using a 7-point (Likert) scale throughout the interview and the unstructured (open-ended questions) will be completed by written response in your own words. Each of the nine sections of the survey will also include an introductory definition to provide consistent understanding regarding the specific types of questions that will be asked and what type of response we are looking for.	
Context	The context for the blood pressure exam workflow will be assessed.
Process Time	The time involved in the blood pressure exam workflow will be calculated.
Process Quality	The information quality will be evaluated in this section, including the importance and relevance of the information available at each step of the blood pressure exam workflow.
Technology	The technology utilized in the blood pressure exam workflow will be assessed based on your perspective of how "useful" and "easy-to-use" the technology is in reference to each step in the workflow.
Attitude	We will evaluate a comparison of users' attitude toward using the technology incorporated in the blood pressure exam workflow.
Behavioral Intent	We will be evaluating a comparison of users' behavioral intent toward using the blood pressure exam workflow.
Outcomes: Awareness	How aware are others (Dr., nurse, office staff, etc.) of your goals for each step in the blood pressure exam workflow.
Goal Alignment	The perception regarding goal alignment with participants in the blood pressure exam workflow will also be evaluated.

Please note that the investigators may stop the study or take you out of the study at any time they judge it is in your best interest. They may also remove you from the study for various other reasons and can do this without your consent. Such unlikely events may have to do with a recent change in a participant's availability to be involved in the study for unforeseen medical reasons.

RISKS

We believe there are no known risks connected to participating in this study since blood pressure readings are common and classified as noninvasive activities that all hypertensive and prehypertensive patients would already be accustomed to. There may however be some risk associated with this study that we are not aware and are unable to predict. Please note that this study does not assume any responsibility for your blood pressure readings, it is important that you review your blood pressure readings with your Doctor should you have any concerns or questions.

BENEFITS TO TAKING PART IN THE STUDY?

It is reasonable to expect the following benefits from this research: Participants of the study will gain a heighten awareness of each step of the blood pressure workflow and formalize their perspectives about the effectiveness of this workflow. Participants will also learn about the specific triggers that accelerate blood pressure and tips to reduce hypertension risk.

We cannot guarantee that you will personally experience benefits from participating in this study; however, others may benefit in the future from the information we find in this study. Specific benefits that others may receive from the information uncovered in this study include, but are not limited to the following. Better understanding for micro-device suppliers of the collaborative requirements that clinicians and patients have in an integrated workflow. Better comprehension of the critical collaborative aspects of the workflow for Doctors intending to deliver more patient-centered care that incorporates new technology into the workflow. Other researchers will also benefit from the generalizability of the collaborative space evaluation model and methodology development for this study for use in other diverse domains.

CONFIDENTIALITY

We will take the following steps to keep information about you confidential, and to protect it from unauthorized disclosure, tampering, or damage: All information collected through the semi-structured interviews will be transferred to a database/spreadsheet and the original collection material will be destroyed by shredding. The participant entries will be coded as participant numbers such that no personal references will be made on any material or data files. The key-code for the participants will be stored in a separate data file that will be encrypted and password protected. All survey data will be encrypted and password protected. The summary data generated from the analysis of the semi-structured interview will be anonymized by a classification of Male/Female, Age, and with/without the technology; there will never be any correlated data that maps back to the individual study participants by name at any level throughout this study. In some cases, it may be necessary, for your safety or for the integrity of the study, for individuals from the HSRO or appointed by the HSRO, institution staff, IRB or sponsor to access your data. In such cases the data will be encrypted, password protected, and anonymized data that has been coded to participant numbers without participant names.

INCENTIVES

Each participant will receive a blood pressure monitor device for use during the study, following the study, each study participant will be able to keep that device for their own unrestricted personal use.

YOUR RIGHTS AS A RESEARCH PARTICIPANT

Participation in this study is voluntary. You have the right not to participate at all or to leave the study at any time. Deciding not to participate or choosing to leave the study will not result in any penalty or loss of benefits to which you are entitled, and it will not harm your relationship with RIT. To withdraw from this research study please contact the principal investigator via the email listed above and make your request to withdraw in an email note, please include your name and contact information in the email note.

CONTACTS FOR QUESTIONS OR PROBLEMS?

Contact Prof. Chris Bondy at 585-475-2755 or via email at cxbppr@rit.edu if you have questions about the study, any problems, unexpected physical or psychological discomforts, any injuries, or think that something unusual or unexpected is happening.

Contact Heather Foti, Associate Director of the HSRO at (585) 475-7673 or hmfsrs@rit.edu if you have any questions or concerns about your rights as a research participant.

Consent of Subject

Signature of Subject Date:

____

Upon signing you agree to participate in this study under as stated herein, you will receive a copy of this form, and the original will be held by the researcher in the subject's research record.

Research Abstract: *A Method for Exploring the association between Current-State and Enhanced Future-State Technology-Mediated Collaborative Workflow – Hypertension Workflow Example*

New technologies impact the way we function in our daily lives; both from a personal perspective, as consumers, and in our professional lives, as knowledge-workers. The integration of new technology into collaborative workflows introduces many variables that are of great concern to companies, organization, and individuals; such as the costs of development, the switching-cost associated with migrating from the current workflow to the future workflow, details of how the future workflow functions compare to the current workflow – what processes should be avoided, what should be retained, and what should be revised, and how users behavior is associated with adoption of the new technology, etc. Organizations have a difficult time determining the scope of a new technology initiatives, including how the capability and complexity of new technology will provide measurable benefit in some quantified/qualified way compared to the current workflow.

This research is focused on the development and testing of a model and methodology (approach) to evaluate the association between the way individuals in a workgroup currently perform a work-process (current-state workflow) compared with the way they complete that same work-process with the help of a "technology-mediated workflow".

The Collaborative Space – Analysis Framework model and methodology (CS-AF, introduced in this research) establishes a baseline-view or ground-truth perspective of the current-state workflow from five key areas: Context, Technology, Process, Attitudes, and Outcomes. Each of the five elements of the CS-AF model provides a unique vantage point and associated measures for comparison. The CS-AF methodology includes a procedural process for conducting collaborative workflow research using the CS-AF. All information is collected on-site though detailed workflow audits, and semi-structured interviews with the participants in the workflow. When all the data for both the current-state and future-state workflows are collected, the two workflow scenarios are evaluated and analyzed and a summary perspective is derived.

The Health Information Technology (HIT) domain is interested in Dr.-Patient collaboration and the use of new technology to help facilitate a system-wide migration to patient-centered healthcare. HIT researchers are working to define appropriate models that can be used to evaluate and improve the current-state workflow and collaborative participation between Doctors and patients (Eikey, Reddy, Kuziemsky 2015). The CS-AF will be used to evaluate and compare the technology-enabled solution versus the tradition workflow. The 5-step CS-AF approach planned for this research is illustrated in the diagram below.

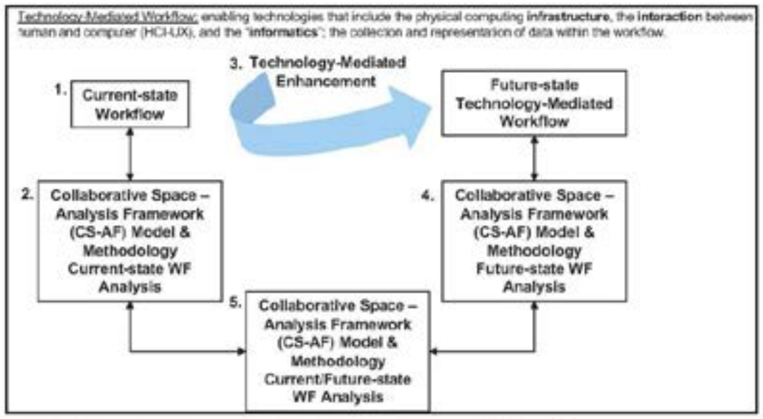

Figure 1: Collaborative Space - Analysis Framework Research Methodology

This research is focused on the workflow scenario for hypertension outpatients who need their blood pressure measured by a clinician (current-state workflow). Hypertension is a global and indiscriminate condition that effects on average over 25% of the adult population worldwide. One of the dilemmas associated with hypertension treatment is obtaining timely and accurate patient blood pressure readings. The current hypertension workflow requires patients to schedule and attend a visit to the doctor's office where the blood pressure reading is performed by a clinician. This current hypertension workflow process is not only time-consuming, it is also riddled with a variety of issues that affect the very accuracy of the blood pressure readings; such as, time-of-day, white-coat syndrome, patients food consumption, hours of sleep, amongst other variables.

This research includes the development of a future-state technology-mediated workflow that incorporates a cloud-based mobile app and portable blood pressure monitor that has been integrated with a smartphone allowing hypertension patients to conduct daily blood pressure readings in the convenience of their home. This infrastructure delivers a secure and easy to use system for BP reading with an interface that allows the user to monitor the statistics of their blood pressure readings. The BP readings are averaged daily (or by selected range) to provide a more accurate representation of the patient's true blood pressure. Patients also receive wellness data based on their specific health profile associated with hypertension accelerators such as smoking, salt intake, diet, exercise, weight, and alcohol consumption.

The current-state and future-state technology-mediated workflow for hypertension outpatients will be evaluated using the Collaborative Space – Analysis Framework developed for this research.

Appendix C

Wise&Well Usability Study

1. Wise&Well App – Usability Test

Prior to conducting the blood pressure field trial, a comprehensive usability test was conducted to validate the functional use of the technology-mediated solution with respect to the target participant users. Since the manual wrist-cuff used for Group 1 (manual workflow group) incorporated existing technology and manual logging of BP readings, there was no usability test for this system, however complete documentation, a training video, and one-to-one support was provided to both groups during the actual field trial. For this usability test, a minimum of one user was selected for each of the 6 age-bands represented in this study. The participants involved in this usability test adhered to the followed the test procedures and were disqualified from the subsequent field trial.

The usability test was designed to elicit feedback from participants that resemble identical profiles of the target users intended for the blood pressure exam field trial. Four use-cases were included in this usability test and a consistent set of usability metrics were evaluated through an online survey that each usability test participant conducted at the conclusion of the usability 4-day minimum test period.

The objective of this usability test was to evaluate the user acceptability across three areas of usability, (1) Ease-of-Use, (2) User-Friendliness, and (3) Functional Acceptability as it pertains to four (4) specific use cases that were intended for the blood pressure exam workflow field study. The scope of the usability study is the intended technology-mediated workflow that will be used for collaborative blood pressure exam workflow study incorporating the Omron blood pressure device and the Wise&Well smartphone application (the "system"). The objectives for each area of the usability test and use-case scenarios are summarized below.

- **Ease-of-Use:** Evaluation of the system with respect to each functional task required to complete the objective of each of the use cases; this validation of the functionality assesses how intuitive and straightforward is the system with respect to each task.
- **User-Friendliness:** Evaluation of the logical and easy access to each step necessary to complete the task (heuristics/accessibility: external/internal consistency, efficient and understandable user-experience (affordances, signifiers, messages).
- **Functional Acceptability:** Evaluation of the overall system functionality, does the system enable a viable workflow and contextual operation, with a clear indication of where you are in the system at any time and how to navigate appropriately and obtain the desired results of each task.

Each of the usability factors listed above was evaluated in the context of the following use cases. Usability test participants were provided with a test packet which includes the identical items planned for the blood pressure field trial, including printed and online user documentation and the Omron bicep-cuff blood pressure monitor. The documentation describes and illustrates the Wise&Well (W&W) app download and install procedure, app setup (app registration and device pairing procedure), and twice-daily blood pressure exam procedure.

- Use Case 1: Download and Installation of W&W Application – from Google Play (Android) and Apple TestFlight (iOS) respectively and installation of the app on the user's smartphone.

  Note: the Omron HEM-9200T BP device has been validated by Omron Corporation as a fully tested, AHA approved commercial BP device, and validate by Dr. Grover, MD for this research study.

- Use Case 2: Wise&Well Application Setup and Registration – upon completion of the W&W app install all usability testers were instructed to register on the W&W app, pair their Omron BP device using the Bluetooth service and conduct an initial test BP reading.

- Use Case 3: Twice-Daily Blood Pressure Readings using the W&W app – Usability testers were instructed to complete 2 blood pressure reading in the am (on minute apart) and two BP reading in the pm per a specific test protocol established by the American Heart Association using the W&W app.

- Use Case 4: Evaluation of Overall Wise&Well Application Performance – Following a minimum of 4 consecutive days conducting twice-daily blood pressure exams, usability testers were asked to complete an online survey designed to evaluate the overall functionality and user experience of the system.

The Usability Test survey included Likert-scale survey questions in the areas of ease-of-use, user friendliness, and overall functionality per the four use cases described above, in addition, open-ended subjective questions were included to more individual commentary on the usability and issues associated with the system.

2. Usability Test – Survey Results and Analysis

The Usability Test survey is included in Appendix C and included a range of usability survey questions that were rated using a 7-point Likert-scale as well as open-ended subjective questions, summary of the data collection and analysis follows.

Demographics: The Usability Survey incorporated a variety of target users with a minimum of 1 user per each of the 6 age-bands that are intended for the field test and discussed previously. Other relevant demographic data from the Usability Test participants is listed below:

Total Usability Test Participants: 8

Male vs. Female test participants: 2 - Male, 4 - Female

Smartphone (iPhone vs. Android): 7 - iPhone, 1 – Android

Use Case 1: Download and Installation of W&W Application – Survey Results

Q1.1: Was the W&W app download and install intuitive and straightforward to accomplish the task?

1	Yes	62.50%	5
2	Somewhat	37.50%	3

Q1.2: Did you experience any difficulty with this task? If yes, please explain.

1	No	50.00%	4

2	Yes, Please explain	50.00%	4

Q1.2: Participant Comments:

- Profile did not initially save
- password didn't work but I typed in 1 number incorrectly when I saved it so I didn't realize that until I had to ask for help
- The system hung up during registration but I think that was because I had started the registration process on the first version. When I logged out and logged in again it worked fine.

Q1.3: Is there any part of the process that could be improved? If yes, please explain.

1	No	75.00%	6
2	Yes, Please explain?	25.00%	2

Q1.3: Participant Comments:

- I believe some participants will need help downloading the app during a video conference

Q1.4: How would you rate your experience to download and install the WW app?

1	Excellent	37.50%	3
2	Good	62.50%	5

Q1.5: Was the WW app download and install logical with easy access to each step necessary to complete the task? If no, please explain.

1	Yes	87.50%	7
2	No, Please explain why?	12.50%	1

Q1.5: Participant Comments:

- Had multiple Gmail accounts and discovered it had to be connected to the Gmail account related to my installs...this may only be a test related impact.

Q1.6: Was your experience involved in completing the download and install easy to understand (clear and concise), and easy to complete?

1	Yes	100.00%	8
2	No, Please explain why?	0.00%	0

Q1.7: Was there a clear indication of where you were in the process and how to navigate appropriately?

1	Yes	100.00%	8
2	No, Please explain why?	0.00%	0

Use Case 2: Wise&Well Application Setup and Registration – Survey Results

Q2.1: Was the setup and registration intuitive and straightforward to accomplish the task with the W&W app?

1	Yes	62.50%	5
2	Somewhat	37.50%	3

Q2.2: Did you experience any difficulty with W&W setup and registration process?

1	No	25.00%	2
2	Yes, Please explain	75.00%	6

Q2.2: Participant Comments:

- Profile did not initially save
- my password wasn't working b/c I typed it in and saved it incorrectly
- Until I read the written directions. :)
- I think I had issues with the system hanging up because I had previously started the registration process on the original version. I had to close the app and clear history before logging in again and instead of trying to create an account I just used existing user and then it worked fine.

Q2.3: Is there any part of the W&W setup and registration process that could be improved? If yes, please explain?

1	No	75.00%	6
2	Yes, Please explain?	25.00%	2

Q2.3: Participant Comments:

- for some less techy participants be with them when they do the initial install
- The diet portion - My diet doesn't just consist of one thing. It was a combination of things

Q2.4: Rate your experience with the W&W setup and registration process?

1	Excellent	25.00%	2
2	Good	62.50%	5
3	Neither Good nor Bad	12.50%	1

Q2.5: Was the W&W setup and registration process logical, with easy access to each step necessary to complete the task?

1	Yes	100.00%	8

Q2.6: Was your experience involved in the W&W setup and registration process easy to understand (clear and concise), and easy to complete?

1	Yes	100.00%	8

Q2.7: Was there a clear indication of where you were in the process and how to navigate appropriately and obtain the desired results to setup and registration with the W&W app?

1	Yes	100.00%	8

Use Case 3: Twice-Daily Blood Pressure Readings using the W&W app – Survey Results:

Q3.1: Was conducting twice-daily blood pressure readings using the W&W app intuitive and straightforward to accomplish the task? If no, please explain?

1	Yes	87.50%	7
3	No, Please explain why?	12.50%	1

Q3.1: Participant Comments:

- At first I didn't realize that I had to log into the app prior to taking a blood pressure

Q3.2: Did you experience any difficulty conducting twice-daily blood pressure readings using the W&W app? If yes, please explain?

1	No	87.50%	7
2	Yes, Please explain	12.50%	1

Q3.2: Participant Comments:

- forget initially but as days went on it became more intuitive

Q3.3: Is there any part of conducting blood pressure readings using the W&W app that could be improved? If yes, please explain?

1	No	75.00%	6
2	Yes, Please explain?	25.00%	2

Q3.3: Participant Comments:

- Update process to guide user to perform the bp prior to connecting
- it kept saying it was connecting after second reading. This was confusing

Q3.4: Rate your experience with conducting twice-daily blood pressure readings using the W&W app?

1	Excellent	75.00%	6
2	Good	25.00%	2

Q3.5: Was the W&W app logical, with easy access to each step necessary to conducting twice-daily blood pressure readings? If no, Please explain why?

1	Yes	87.50%	7

2	No, Please explain why?	12.50%	1

Q3.5: Participant Comments:

- Once I understood what I needed to do it was very easy. I think I missed a written instruction in the beginning which caused a little challenge

Q3.6: Was your experience involved in the W&W app to conduct twice-daily blood pressure readings easy to understand (clear and concise), and easy to complete?

1	Yes	100.00%	8
2	No, Please explain why?	0.00%	0

Q3.7: Was there a clear indication of where you were in the process and how to navigate appropriately and obtain the desired twice-daily blood pressure readings using the W&W app?

1	Yes	100.00%	8
2	No, Please explain why?	0.00%	0

Use Case 4: Evaluation of Overall Wise&Well Application Performance – Survey Results:

Q4.1: Rate the overall Ease-of-Use of the W&W app?

1	Excellent	50.00%	4
2	Good	50.00%	4

Q4.2: Rate the overall User Experience of the W&W app?

1	Excellent	75.00%	6
2	Good	25.00%	2

Q4.3: Rate the overall Usefulness of the W&W app?

1	Excellent	75.00%	6

2	Good	25.00%	2

Q4.4: Were there any issues with the User Experience? If yes, please explain?

1	No	87.50%	7
2	Yes, Please explain?	12.50%	1

Q4.4: Participant Comments:

- Alerts to consult a doctor would repeat even after acknowledging them. Sometimes typing would not visually register but it was capturing what was being typed.